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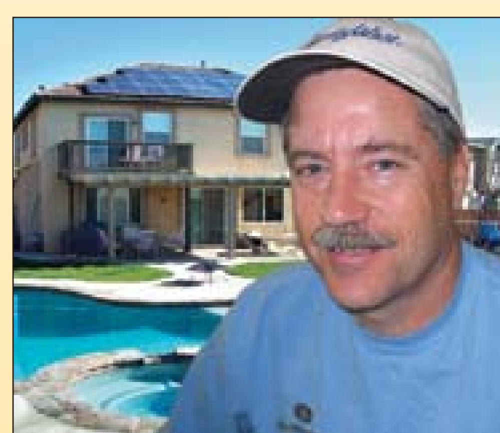
- GE Brilliance™ Grid-tied Power Inverter
- GE Remote Energy Monitor
- Roof-Mount Solar Module Mounting Rack
- ReadyWatt® Combiner Box, Wiring, and Disconnects



Installed by a solar professional near you…

When you call we will refer your inquiry to a local professional who is well acquainted with solar in your area. You will learn about the features of the GE Brilliance™ Solar Appliance, and the benefits of installing one in your home. Your dealer will visit your home, looking at sun exposure, power usage, incentive programs, and more to help you choose the system that is right for you. Expect excellent service before, during, and after installation from GE, Energy Outfitters, and your local solar professional.

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August & September 2006

On the Cover
Renewable energy professionals Scott Ely of Sunsense Inc. and Soozie Freidmar of Solar Energy International in Carbondale, Colorado.

Photo by Chrissy Leonard

Regulars

An Audience of Millions

Sitting in front of the TV, I found myself groaning and cheering like a football fanatic. *Larry King Live* was on, the topic was energy, and I was glued to the tube. It was prime time. This program regularly pulls in a million-plus viewers, and dwindling oil supplies and renewable energy solutions were on the table. It was a supersized opportunity for renewables to catch the attention of the U.S. mainstream.

A roundtable discussion was underway with panelists that included Chevron CEO David O'Reilly, Senator Kay Bailey Hutchison of Texas, Senator Dick Durbin of Illinois, and Sir Richard Branson, founder and chairman of the Virgin Group, which owns and operates Virgin Atlantic Airways.

O'Reilly discussed how global demand for petroleum is up, as is the competition to control supplies, and that no single solution (or resource) will solve the problem. Senator Hutchison also called for a diverse energy mix. Senator Durbin clearly made the connection between shrinking petroleum reserves, the need for more efficient vehicles in the United States, and the growing economic threat posed by climate change. A hip-looking Branson spoke of the skyrocketing cost of fueling his airline, and his ongoing investments in ethanol refineries, wind farms, and other renewable technologies.

As the panel discussion progressed, I was encouraged by the fact that it was even taking place. At the same time, I was incredulous that this particular panel was chosen. Many of the thousands of *Home Power* readers we hear from each year could have more clearly outlined the energy hurdle in front of us, and the role renewables and efficiency will play in a sustainable energy future.

While most of us will likely never have an audience of millions, a million informed individuals talking with friends and neighbors about renewables and energy efficiency has an even greater effect. We're all responsible for shaping our energy future, one conversation at a time.

—Joe Schwartz for the *Home Power* crew

Think About It...

"It is difficult to get a man to understand something when his salary depends on his not understanding it."

—Upton Sinclair (1878–1968)

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HP staff

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Home Power Inc.
PO Box 520, Ashland, OR 97520 USA
800-707-6585 or 541-512-0201
Fax: 541-512-0343
hp@homepower.com
mailbox@homepower.com

Circulation: Shannon Ryan & Jacie Gray
subscription@homepower.com

Advertising: Connie Said & Kim Bowker
advertising@homepower.com

Marketing & Resale: Scott Russell
marketing@homepower.com

Editorial Submissions: Michael Welch
submissions@homepower.com

www.homepower.com

Ask the EXPERTS!

Electric Sticker Shock

I am a homeowner in Texas and I'm looking for information on converting an all-electric house built in the mid-1970s to a fully self-powered solar home. Have you published any articles that would address this? I recently looked at the electric bill and I thought I was headed to the intensive care unit at our local hospital.

Pat Bristol • via e-mail

Hi Pat, The number one thing to do is to figure out how to consume less energy. It is a lot cheaper to buy energy efficient appliances than it is to buy solar-electric modules to power inefficient ones. Many folks can achieve a 50 percent decrease in electrical usage by making their households more efficient. Start by installing compact fluorescent lightbulbs in place of incandescent ones. They are about four times more efficient, and have improved remarkably and gotten less expensive in the last two to three years.

Add insulation to your home, install better windows, and even add window coverings to help use less energy for heating and cooling. Make sure that your conditioned air is not leaking to the outdoors through the cracks and crevices that are in many homes. Put your domestic water heater on a timer so it only goes on an hour before you usually need hot water. Invest in new, energy efficient appliances. Newer, more efficient refrigerators use one-third to one-half as much energy as older ones.

Figure out how to consume less—turn lights out when nobody is in a room, put always-on appliances like TVs, VCRs, stereos, and microwave ovens on switched outlets. Dry clothes on a clothesline.

Then consider putting in a solar hot water system. They are usually more cost effective than solar-electric systems. Have a pool? If so, you should definitely install a solar pool heater.

Finally, work towards that solar-electric system. It will be a *lot* less expensive if you have done the other things first.

Michael Welch • Home Power

Microhydro Pipe Dilemma

I am a homesteader in northern California and I just installed a Stream Engine microhydro turbine. The turbine is working well, but sometimes I have a problem in this siphon system. I have a 6-inch PVC pipe for the intake and run to the turbine. It is submerged in the pond, and the pipe exits and runs over the top of the pond's berm. The flow is about 150 gallons per minute (gpm) at approximately 15 feet of head. The problem? At the top of the berm, which is also the highest point of the pipe, an air bubble is getting trapped. The siphon will still run, but the turbine amperage is reduced. The air bubble doesn't always develop. I have run the system for days with few or no air bubbles. At other times, I get a large air bubble. Solutions? Look for a cheap hand vacuum pump to suck air out of the pipe?

Darryl • via e-mail

Hi Darryl, Your solution is easier than that. Since you apparently know the high point, get an air purge valve from a solar hot water dealer. When you're ready to install it, drain the pipeline—unless you need a shower. Drill and tap the valve into the PVC. Problem solved. In high head (pressure) systems, add a PVC tee and threaded reducer bushing, instead of tapping directly into the pipe. Good luck,

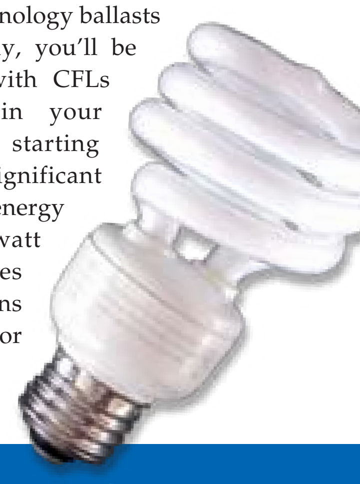
Bob-O Schultze • Electron Connection

Lightbulb Choice

My husband and I are building a new home. We had planned to buy all compact fluorescent fixtures. However, we are now being told that if we are going to be in and out of a room (like the kitchen pantry, or a hallway), it is better to use an incandescent light (with a dimmer) rather than a compact fluorescent light (CFL). My understanding is that CFLs have an initial high energy surge, and if I am turning on a light, then quickly turning it off again, I do not leave the CFL on long enough for it to run efficiently. In these cases, turning on and off an incandescent bulb is supposedly more energy efficient. Thank you.

Marie • via e-mail

Greetings Marie, I applaud your habit of turning off lights when leaving a room. I have not found any conclusive evidence to suggest using an incandescent over a 2006 CFL that meets stringent Energy Star specs or better. Buy that CFL fixture today and you should have a ballast that lasts 10,000 to 30,000 hours and will save you lots of energy! Using excellent-quality, quick-fire technology ballasts available today, you'll be well ahead with CFLs everywhere in your house. The starting surge is insignificant in terms of energy use. A 15-watt CFL provides enough lumens for a hallway or pantry instead



of a 60-watt dimmable incandescent. Best regards,

Geoffrey Talkington

Solar Heat Storage

I am interested in solar collectors for space heating with storage (either concrete, rocks, or water), and was wondering if you could suggest anything. I am having trouble finding information and am wondering if it is a worthwhile plan to pursue. I find tons on solar water heating, but information on space heating with storage is limited. Thanks,

Michael Clark • via e-mail

Hello Michael, There were thousands of active solar heating systems with storage installed twenty or more years ago that are still operational today. Because of the high initial cost of many of these systems, they are dependent on tax incentives for their popularity.

I will only address thermal storage as it applies to active solar heating systems that I am familiar with, although there is a lot of overlap with some passive systems. Books from the early 1980s have some good information about storing solar energy, but they also have some info that has been proven wrong in the ensuing years.

Water has a relatively high specific heat, is inexpensive, easy to store, and easy to transport through piping. Because of this, it is the storage medium most often used with solar heating systems. The only big considerations are the tank and system design. I recommend that large, unpressurized tanks (more than 120 gallons) be constructed of fiberglass with a high-temperature liner, stainless steel, or polypropylene. Concrete and mild steel tanks have been successfully used, but they are thick and very heavy. Other materials like lower-density polyethylene and EPDM have proven to have very limited lifetimes in large tanks.

Concrete and brick floors are used for storage in radiant floor systems. Solar heating systems integrate nicely with radiant floor systems because of the low operating temperature and the built-in storage if the radiant tubing is embedded in concrete. Concrete and brick have specific heats of about 0.2—or one-fifth of the specific heat of water. Specific heat is a way to quantify any material's heat content or ability to act as a thermal battery. Compared with water, the same volume of concrete or brick cannot hold as much heat at a given temperature, but because the weight of concrete is about triple that of water, the water will hold less than twice as much heat in the same volume.

Rock bins and eutectic salt (phase-change material) storage systems have rarely worked out for numerous reasons—please take my word that they have unforeseen problems after installation. Cinder blocks turned on their sides and capped with concrete have been used successfully as storage systems for air collectors, but this is not a widely used design.

I suggest that you make your search queries on the Web very specific when researching any of these different storage systems. If you can't find anything there, you might search online booksellers for older solar heating books. Cheers,

Chuck Marken • AAA Solar

PV Payback

I installed a solar-electric system on my home a number of years ago, and I'm very happy that most of my family's electricity comes from an environmentally friendly source. Visitors often ask about payback. I'm not a number cruncher, and I'm wondering how I can answer the financial payback question.

Rich Hogue • Tucson, Arizona

Rich, The financial payback on your investment is subject to many factors:

- The structure and value of financial incentives where you live, such as tax credits and rebates
- Utility regulations, such as feed-in tariffs and net metering laws
- Utility rate structures, such as tiered rates (that is, rates that start low and rise as you consume more electricity) and time-of-use metering
- Future increases in utility rates where you live
- Your local climate and solar resource, which affects the number of kilowatt-hours you produce relative to your investment
- Your system's performance, which is generally a result of the quality of design, installation, and operation of the system
- Whether your installation is residential or commercial, which is tied to tax structures
- Whether you include the cost of financing your system
- Whether you can amortize your system cost into a mortgage
- Whether you can quantify an increase in the appraised value of your property

I wish I could offer an easy answer, but any one of these factors can make your solar energy system investment a "good" or "bad" financial investment. My answer is as much an indictment of a financial structure that values immediate rate of return over long-term social and planetary health. See Andy Kerr's article, "Mixing Business with Pleasure," in *HP101* for one person's detailed financial analysis of one situation.

Allan Sindelar • Positive Energy

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Install A Solar-Electric Roof

John Witte

Nailing down the PV shingles is similar to installing regular composition shingles.

Building-integrated photovoltaic (BIPV) systems integrate solar-electric materials into a building's exterior skin. Residential BIPV roofing options include PV shingles or tiles, and PV laminates on metal roofing. PV shingles are one BIPV option for homeowners, converting roofing into a source of electricity.

Homeowners concerned about aesthetics can choose PV shingles for new construction or for re-roofing existing homes. PV shingles meet the needs of homeowners in locations that otherwise restrict the installation of solar-electric modules, satellite dishes, and antennas. Another advantage is saving money. A homeowner will save on conventional roofing materials, PV mounting frames, and hardware—and, of course, energy too.

United Solar Ovonic's PV shingles use flexible thin-film solar cells of amorphous silicon on a 5-mil (0.0127 mm) stainless steel substrate. They are encapsulated in a weather-resistant polymer, and blend into the roofing pattern of conventional fiberglass or asphalt shingles. The shingles carry a 20-year warranty on electrical output, and are rated to withstand 80 mph (36 m/s) winds. The PV shingle is nailed in place with common roofing nails over 30-pound felt underlayment.

Uni-Solar PV Shingle Specs

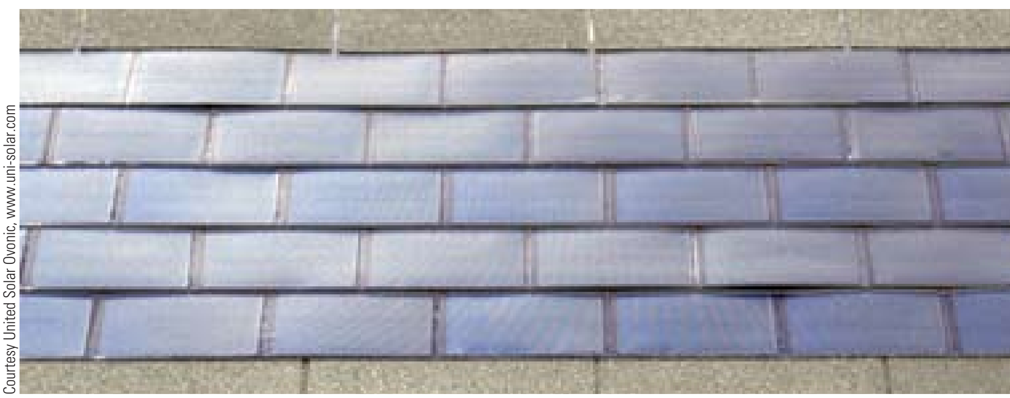
- Model: SHR-17
- Shingle length: 86.4 in.
- Shingle width: 12 in. (5 in. exposed area)
- Minimum roof slope: 3:12 (15 degrees)
- Maximum roof slope: 21:12 (60 degrees)
- Rated power: 17 W
- Maximum power point voltage: 9 Vmp
- Open-circuit voltage: 13 Voc
- Short-circuit current: 2.4 A
- Power output warranty: 20 year

Courtesy United Solar Ovonic, www.uni-solar.com

Installing PV shingles on a hip roof can be complicated, requiring some advance planning.

Below: Wiring leads on the back of a PV shingle.

Courtesy United Solar Ovonic, www.uni-solar.com



Several courses of PV shingles seamlessly integrate into a typical composition roof.

Planning & Layout

A lot of pre-installation planning is required to assure a clean and code-compliant PV shingle project. When installing on new construction, planning your PV system with the architect during the building design stage is critical. When installing on existing buildings, care must be taken to examine the roof structure, paying close attention to construction type, spacing of framing members, and working space in the attic. You must carefully consider the roof areas and dimensions of the roof sections.

Installing PV shingles on simple gable roofs is the most common installation. Each horizontal course of shingles is offset from the course below it by half a tab, or $3\frac{1}{2}$ inches (9 cm)—this is standard shingle roofing practice. When you're done installing the PV shingles, you have two vertical columns of wires $3\frac{1}{2}$ inches apart, which are routed through two parallel raceways under the roof deck between the rafters. A hip-roof installation takes on a trapezoid shape, with a single line of wires that cross rafter spaces and can easily hit rafters or blocking, and interrupt the required continuous raceway.

The high DC input voltage of grid-tied inverters calls for 30 to 40 shingles wired in series. This may require 100 to 120 square feet (9–11 m^2) of unshaded roof area for one series string. A 1 KW array of solar shingles is approximately 60 shingles and 180 square feet (17 m^2). The efficiency of the shingle is about half that of a crystalline module. This means that the roof area needed for a 1 KW PV shingle array is approximately twice that of a crystalline array.

Installing PV Shingles

PV shingles are installed on sloped roofs that have at least a 3:12 pitch, to provide adequate weather protection. Allow for about five courses of conventional shingles at the eave and peak to allow for the working clearances required by the *National Electrical Code.*

The PV shingle is installed like a conventional three-tab or dimensional shingle. Plan the shingle layout so the wires fall between the rafters to make the wiring connections easier. Nail the shingles to the roof with conventional roofing nails. The positive and negative bus bars, encapsulated in the shingles, run in the area $1\frac{1}{2}$ inches (38 mm) above the cells, so follow the nailing instructions that come with the shingles.

Making the wiring connections and containing the series string wiring in conduit is a complicated and time-consuming task. Each shingle requires a hole to be drilled through the

Drilling the wiring holes before nailing the PV shingles.

plywood roof sheathing so the wires can be inserted and then connected to the other shingles to complete the array wiring. United Solar provides a cardboard template to help installers mark the locations for the wires. The template has to be placed very accurately so that the holes for the wires will be precise and shingles are properly placed for even exposure and to avoid shading other cells or pinching the wires. Snap chalk lines up the roof to provide guidelines for the template.

Since wiring connections need to be accessible, shingles should not be installed on overhangs, or other sections of roof where there is no access to the wiring below the roof deck. You cannot cut a PV shingle, so make sure you will have adequate area for the shingle length and the multiple series wiring connections of the low-voltage shingles.

Since 1998, my company has followed United Solar's recommendations, and has used a plastic surface raceway like Panduit for series string wiring and connections. The base strip of the Panduit is drilled to match the holes in the roof and secured to the underside of the roof deck with 3/8-inch screws. We use a 7/8-inch drill bit to make our holes in the roof, and a band saw, miter saw, or hacksaw to cut 1/2-inch-long pieces of 1/2-inch PVC conduit. The PVC pieces are inserted into the holes in the roof before securing the Panduit. Another raceway option is manufactured by Wiremold. The G4000 raceway product is steel, and UL listed for use up to 600 volts.

Wiring PV shingles can be tedious work—requiring more than 60 connections for each rated kilowatt of PV array, many times in less-than-ideal conditions. Use a good crimping tool and weather-resistant butt connectors to make reliable, long-term connections. Give the wires a good tug and measure the open circuit voltage as you go to ensure good connections. Parts for the plastic surface-mount wire raceway include snap-together inside corners, outside corners, 90-degree base and cover pieces, and junction boxes. Terminate the module interconnect wiring in a J-box, and run THHN-2 or THWN-2 in metallic conduit, or run armored cable to the combiner box, disconnect switch, and inverter.

Solar-Electric Roofing

PV shingles are just one option for installing a solar-electric system on your home, and they have their advantages and disadvantages. On the downside, wiring PV shingle systems

Code Issue

United Solar Ovonic received UL approval in 1998 to use plastic raceway, mounted below the roof deck, as a junction box for their PV shingles. Section 690.14 of the 2005 *National Electrical Code* requires that PV source circuit and output circuit wires run in *metallic* conduit from the point that the wires penetrate the roof to the first readily accessible disconnecting means. In some jurisdictions, this requirement may prohibit long runs of PV source and output circuits inside a building before reaching the code-required PV disconnect.

The best approach to installing PV shingles is still under discussion. The skilled professionals who continue to develop better techniques to install PV shingles, as well as the other renewable energy technologies, are helping to standardize the industry and encourage satisfaction and ownership of solar energy systems.

Making series connections in the raceway.

PV shingles seamlessly blend into this home's rooftop, merging form with function.

is definitely more complicated than module installations, with lots of connections for these low-voltage shingles. And thin-film roof shingles are about half as efficient as crystalline PV modules, so you need more roof space for the same output. But for energy efficient homes with good southern roof exposure, this is not generally a serious limitation.

Chief among the advantages of PV shingles are that they blend in with the existing structure. Another advantage is that the cost of your roofing material and your electrical generating equipment is rolled into one product, so you don't need to purchase separate roofing, modules, and racking equipment. PV racking can be a significant cost of a system, and the labor to assemble and install it is another cost. You also have no exposed roof penetrations with a shingle installation, while with most module racking systems, you have multiple penetrations.

If you want your solar-electric system to blend in with your home's exterior, you should consider BIPV options. Then you can smile whenever the sun shines, knowing that your roof is not only keeping you dry, it's also providing your electricity.

Access

John Witte, Advanced Distributed Generation, LLC, 2600 Dorr St., Toledo, OH 43607 • 419-530-3792 • Fax: 419-530-3793 • jwitte@advanced-dg.com • www.advanced-dg.com

Panduit • www.panduit.com • Plastic raceway

United Solar Ovonic • 800-843-3892 or 248-475-0100 • www.uni-solar.com • PV shingles

Wiremold • 800-621-0049 • www.wiremold.com • G4000 raceway

"Roof-Integrated PV: From Sunbeam to Standing Seam," William Ball, *HP105* • Solar-electric laminates for metal roofing

Choose an Energy Efficient Computer

Mike Chin

The energy consumption of personal computers (PCs) is finally becoming a topic of interest outside the mobile and laptop computing circles. And it's about time. In the United States alone, computers and information-technology equipment account for 2 to 3 percent of our annual electricity consumption, to the tune of US$8 billion. According to the U.S. Energy Information Administration, domestic electricity demand is projected to grow at nearly 1 percent annually, mostly to power computers, electronic equipment, and appliances.

An increasing awareness of these energy issues, the high costs and challenges associated with cooling computer processors, and the lure of a new marketing arena to hype have triggered a new interest in achieving higher efficiencies. The shift began some years ago with Sun Microsystems, IBM, Hewlett-Packard, and others moving towards more efficient central processing units (CPUs). In the past year, Intel—the PC industry's 800-pound gorilla—has finally joined the movement, and has started to flex its considerable muscle in leading the "new" performance-per-watt trend by making more efficient processors.

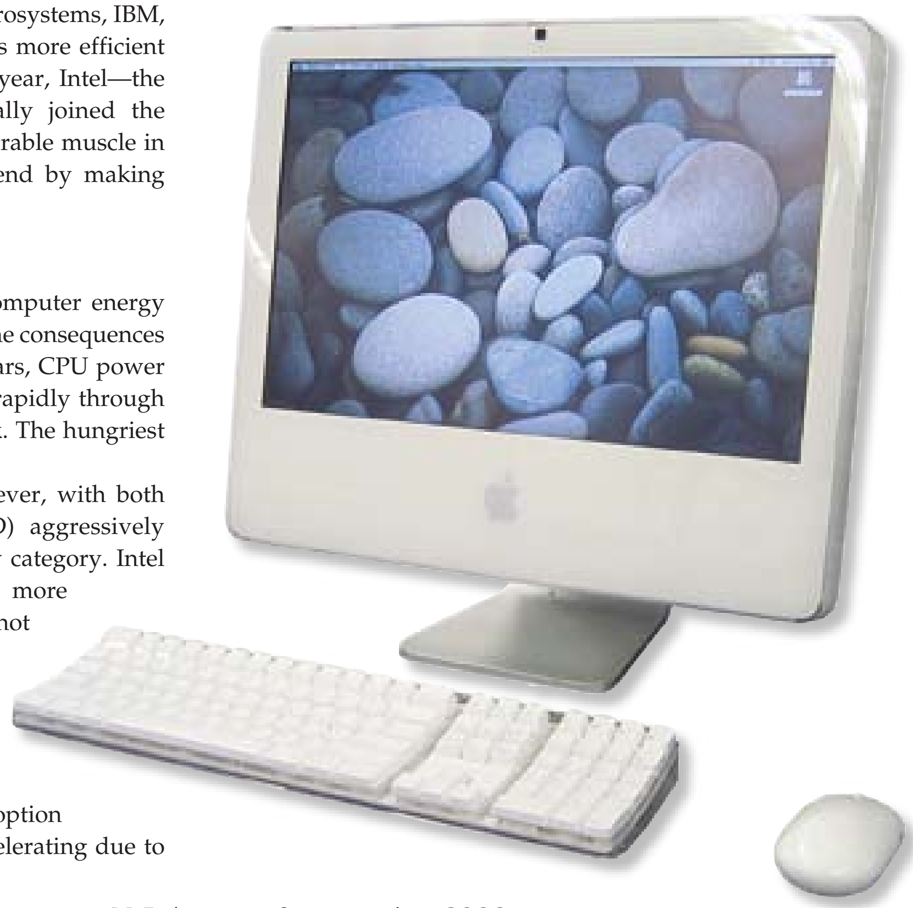
Taming Power-Hungry PCs

In the time of the old 386 and 486 chips, computer energy consumption was still in the single digits, so the consequences were not that serious. However, in recent years, CPU power demand has gone through the roof, leaping rapidly through the double digits, and past the 100-watt mark. The hungriest Intel processors consume more than 150 W.

This is a year of major transitions, however, with both Intel and Advanced Micro Devices (AMD) aggressively introducing new processor products in every category. Intel is finally showcasing new, cooler-running, more powerful chips to replace its aging, ultra-hot Prescott Pentium 4s, and AMD has made further refinements on their technologies.

One of Intel's current strategies is to blur the distinction between mobile and desktop processors, using the same chips for both types of platforms. In fact, the adoption of mobile components for desktop use is accelerating due to

The Apple 17-inch iMac Core Duo is very energy efficient, setting the stage for the future of consumer desktop computers.



17-inch iMac Core Duo

Activity / State	Noise Level (dB at 1 m)	Power (Watts)
Standby	0	2
Low-power idle	20	33
Idle	20	46
Hard-disk seek at idle	21	52
Max CPU load	22	63

Source: *Silent PC Review*

the consumer demands for ever-smaller computers at home and in the office. The new Apple iMac, based on Intel's Core Duo processor, is a perfect example of this trend. The first collaboration between Intel and Apple stuffs an entire PC into the back of a 16.9- by 6.8-inch, widescreen, flat-panel monitor (17-inch model). The CPU is a dual-core model (two processors in one core, based on the idea that two heads are better than one), originally intended for use in laptop computers. It has already been lauded as Intel's best CPU ever.

Silent PC Review (www.silentpcreview.com) reviewed the 17-inch iMac Core Duo, and found it to be the most energy-efficient integrated (monitor and computer, all in one case) PC ever tested—and one of the fastest.

AMD has commanded the top position in processor performance for the past few years. Their Athlon 64 processor's energy consumption has declined, with each new revision showing even lower demand. AMD's lead extends into the dual-core processor arena as well, with the Athlon 64 X2 processors outperforming the Intel Pentium D 800 and 900 series in both processing speed and energy efficiency—the latter is typically half that of a comparable-performance Intel. AMD, which once captured less than 10 percent of the processor market, actually outsold Intel in the first two months of 2006.

Video Cards: Still the Energy Hog

While there is progress on the CPU front, video cards have become the new energy hog in more powerful computers. High-end video cards from nVidia and ATI Technologies (the market leaders) now exceed 100 W peak demand. Both companies offer dual-video card setups for the "ultimate" gaming performance, and this can mean greater than 200 W on two daughter cards. Video cards have not yet been hit with the efficiency bug; we can only hope that the thermal overload that happened with CPUs will soon happen with graphics processing units (GPUs).

Traditional CRT monitors can draw more than 100 watts.

Don't Be Misled by the Label

Before you use the Energy Star label as your guide for buying an efficient computer, consider that the current specs offer no requirements for energy consumption when the computer is in operating mode. Instead, computers are rated by the energy they use while in *sleep* mode. Current criteria stipulate that an Energy Star-qualified computer must enter sleep mode within 30 minutes of inactivity, and must not consume more than 10 percent of its power supply rating in that mode. With these standards, almost *all* computers (about 98 percent) can bear the Energy Star label.

The good news is that the U.S. Environmental Protection Agency (EPA) is working on new Energy Star computer specs for 2007, which include parameters for operating efficiency. At this time of writing, the specs are in their second draft, and propose:

- A high-efficiency (better than 80 percent) power supply must be used. This ensures that electrical energy loss (as heat in the power supply) is kept to less than 20 percent at all times. Currently, a loss of 30 percent or more is typical.
- In standby mode (power off, but AC plugged in), the appliance can draw no more than 2 W.
- In sleep mode, it must draw no more than 4 W.
- In idle mode (powered up, but little or no activity), Category B desktops must draw no more than 50 W; Category A desktops must draw no more than 75 W.

Category B desktops often share the following set of features: one processor with one or two cores; one hard drive; one optical drive (maximum); 1 gigabyte (GB) of RAM or less; a GPU with a single monitor output and 128 megabytes (MB) of dedicated video memory, often integrated on the motherboard. Category A desktops must have at least four of the following: multiple processors; four or more cores on a single processor; two or more GPUs, or a single GPU with less than 128 MB RAM; HDTV-capable video TV tuner; two or more internal hard disk drives; 2 GB or more of installed RAM.

When the new Energy Star spec is implemented in 2007 (January 1, or perhaps July 1), the EPA expects only about one out of every four computers will meet the spec. Then, it will be far easier to choose an energy efficient computer—just look for the Energy Star logo.

Shop Smart—Now

So what if you need an energy efficient computer *today*? You'll be happy to know there are many options.

Get a laptop. Even the most energy-hungry laptop will be relatively modest in its demands, compared to a desktop. The need to conserve battery power means that virtually every component in a laptop computer is designed to run on less energy. Avoid any laptop containing a CPU described as a Mobile Pentium 4. This is a "low"-power version of the desktop P4, arguably the most energy-hungry processor made. Choose instead: Pentium M, Celeron M, Core Solo, and Core Duo among Intel processors; AMD Turion 64 and Turion 64 X2 (dual core) are also very efficient.

If you want the benefits of a large monitor, a full-sized keyboard, and a mouse, all of these can be added to any modern laptop. Plus, some laptops (Apple's new MacBook Pro, for instance) have options for 17-inch screens.

Even this large 23-inch LCD monitor only draws about 65 watts—a big energy savings over old-fashioned CRTs.

Modern laptop computers are fast and powerful, and use only a fraction of the energy of a typical desktop PC.

Get an Apple iMac (Intel Core Duo processor model). These highly efficient, yet powerful, integrated computers can even run the Windows XP operating system. Some Apple dealers are selling them with Windows installed, with dual-boot options. The only downside of these iMacs is that they are not really upgradeable. But because they are high performance computers, upgrading may not be necessary for many years.

Check the energy consumption specs of the desktop PC you are considering. If you can't find the data online, request it from the manufacturer. Keep in mind that idle power consumption is far more important than maximum power, but for overall energy efficiency, it helps if the latter is lower too. In actual use, most computers run close to or at an idle load more than 90 percent of the time. (However, this doesn't hold true if you are an addicted gamer.)

Shop for computers that use 50 W or less at idle, and ideally, not more than 125 W at full load. Power at full load will tend to go higher if the computer has a more powerful video card, which is common with PCs intended for the gaming market. Machines that incorporate "onboard" graphics on the motherboard will generally have the lowest energy consumption. Onboard graphics chips in nVidia and ATI chipset motherboards have decent performance. Try to avoid the Intel onboard graphics chips (Extreme Graphics)—they have poor performance and will be unusable with any modern games.

Avoid gaming video cards if you can. If you must have one, try not to go past the "middle" ranks. Just by itself, a midlevel gaming card at full load can use 50 W, which might be more than the rest of your components—*combined*. And a dual video card PC is an absolute no-no if your goal is energy efficiency.

Know your processors. Look for computers that use Intel Core Solo, Core Duo, "Conroe," Pentium M, or Celeron M processors. Almost all AMD processors, including Athlon 64 single and dual (X2) core, Sempron, and Turion 64 (single and dual core), are quite energy efficient. Generally speaking, choose a middle-to-low clock-speed processor,

unless you have very demanding needs. Most individuals can get by with 1 GB of memory in most cases, and more than two hard drives is a bit of an overkill. You can always add one later, and external USB hard drives are inexpensive, handy, and use no energy when disconnected.

Choose an LCD monitor rather than a CRT. Typical energy consumption of a 19-inch LCD monitor running normally is 25 W to 30 W. In sleep or standby, it will consume no energy at all. In contrast, even an Energy Star-labeled, 19-inch CRT typically draws more than 80 W in normal use. On some 19-inch CRTs, playing a video clip in high resolution can drive usage up to 120 W. When you turn your computer off, and the monitor blacks out, an Energy Star monitor should draw virtually no power, perhaps 1 to 2 W. A non-ES, 19-inch CRT may still use as much as 80 W in this standby mode. (Screensaver modes drop energy use by only about 5 to 15 percent.)

Look for Active Power Factor Correction (APFC) in the power supply. Power factor relates to AC electricity, and the way in which electrical devices interact with the incoming supply. To the power utility, a power factor of 1.0 makes the electric device "look" like a perfect resistance. In such devices, the apparent and real power consumed is the same. An electrical device with a poor power factor (such as 0.5) will draw *double* the apparent power to obtain the same amount of real power. This is easily measured with some AC watt-hour meters (see Access). An APFC power supply in a computer typically achieves a power factor greater than 0.95, compared to 0.7 for power supplies that have passive PFCs, and less than 0.6 for those that have no PFCs.

The power-saving settings window of a Windows XP laptop: Start / Control Panel / Power Options.

A switched plug strip makes it easy to power-down peripherals and phantom loads.

Not all computer specifications will note power factor, and most salespeople won't have a clue. However, you can use these telltale signs:

- An APFC power supply usually has no 120/240 VAC switch; the APFC circuit is tied to an auto-ranging AC input voltage circuit.
- A passive PFC or no-PFC power supply almost always has a 120/240 VAC selector switch.

Turn off the computer and any peripheral devices, such as monitors, printers, and scanners, when they are not in use. Sleep-mode effectiveness for computers varies tremendously—some may use just one-fifth of idle power in sleep, while others will drop barely 10 to 20 percent. At this time of writing, most PCs on the market draw between 65 W and 100 W at idle, and only somewhat less while sleeping. But as 2007 approaches, we're sure to see more energy efficient models. "Hibernation" achieves the same energy savings as turning a computer off—it really is off, but saves the current state of the computer to hard disk, for fast resumption of work upon waking up.

The power-saving settings of a Mac OS X desktop: Apple / System Preferences / Energy Saver.

The energy consumption of printers varies tremendously, with small, slow inkjets drawing little more than 100 W maximum, and high capacity, high volume laser printers drawing more than 1,500 W. However, when idle, their draw is modest, typically less than 25 W. For printers, the difference between idle and sleep modes is usually quite small.

In almost all cases, simply turning the power off is the best way to minimize energy consumption when the machines are not needed. Pulling the AC plug from the wall may save another few watts, but most people will feel this is too inconvenient. "Smart" plug strips like BITS Smart Strip (see Access) can shut off the AC at the plug when the computer itself is turned off, so that you don't have to remember to turn them all off at once.

Access

Mike Chin, *Silent PC Review* • www.silentpcreview.com • mikec@silentpcreview.com

Cooke, Devon, with Mike Chin. "17-Inch Apple iMac—The Official SPCR Review," *Silent PC Review*, 21 April 2006, www.silentpcreview.com/article594-page1.html

Current & proposed Energy Star requirements for computers • www.energystar.gov/index.cfm?c=computers.pr_crit_computers and www.energystar.gov/index.cfm?c=revisions.computer_spec

"Smart" Plug Strips & Watt-Hour Meters:
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Electronic Educational Devices Inc. • 877-928-8701 or 303-282-6410 • www.doubleed.com • Watts Up power meters

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Today's Hybrids

Bradley Berman

There's a bright new light in the otherwise dim and dismal setting of the American car showroom—the hybrid gas-electric vehicle. But hybrids represent a shift in mind-set more than a radical breakthrough in technology.

Among auto consumers, there's a sense that gas-electric hybrid technology might be the fastest solution to the world's transportation energy problems. This enthusiasm should be tempered. Hybrid sales numbers must be viewed in the context of the overall car market. The 200,000-plus hybrid car sales in 2005 represent a little more than 1 percent of the 17 million new cars sold last year.

If every new hybrid driver effectively (and optimistically) doubled fuel economy from 20 mpg to 40 mpg for 40 miles of daily driving, a gallon per hybrid car would be saved every single day. That's a whopping 200,000 gallons per day chalked up to hybrid car drivers. But we would only reduce our daily U.S. consumption from approximately 400 million gallons to 399,800,000 gallons. So hybrids are only a small step in the right direction.

Good Hybrids, Bad Hybrids

Back in the good old days of hybrids—say around 2003—we knew what the word "hybrid" meant. That's not true anymore. The first set of hybrids—the Prius, Insight, and Civic—used a core strategy of reducing the size of the gas engine and providing "on-demand" power from the electric motor and batteries. Reducing the size of the gas engine, which can stand to be smaller based on 90 percent of common driving, is one of the keys to gaining better fuel economy.

The newer hybrids—for example, the Accord, Lexus RX 400h, and Highlander—maintain the conventional size of the gas engine, and add power by way of the electric components. This approach does little or nothing to boost fuel efficiency. In reference to the Highlander Hybrid, Gabriel Shenhar, senior auto test engineer for *Consumer Reports* suggested, "If Toyota had truly wanted to make a fuel-efficient seven-passenger wagon, it could have developed a hybrid from the four-cylinder Highlander with real-world mileage of 30 mpg."

This same criticism could be applied to the Accord Hybrid, which uses a six-cylinder engine for the gasoline-powered half of the power train. Perhaps the good folks from Toyota have taken this feedback to heart. The Camry Hybrid, which started hitting showrooms in May, breaks the U.S. Environmental Protection Agency's (EPA) city 40 mpg mark by keeping the gasoline engine to four cylinders.

Environmental groups, including the Union of Concerned Scientists, Bluewater Network, and the Rainforest Action Network, have criticized the performance-oriented hybrids as a misuse of the term "hybrid." They see the emergence of hybrids with negligible fuel savings as greenwashing.

Jason Mark, program director of the Clean Vehicles Program for the Union of Concerned Scientists, explained to HybridCars.com, "Hybrid vehicles have become the poster children for the fuel economy debate. We are sending signals to Detroit and Tokyo that hybrid technology should be used for fuel economy." Mark and other environmentalists see great value in boosting some hybrids and criticizing others as a way to encourage automakers to produce the greenest hybrids.

It appears that the hybrid sea has parted—with the "real" hybrids offering more than a 50 percent increase in fuel efficiency over comparable conventional vehicles, and the rest left behind as modest improvements to conventional automotive technology.

But what's in a name? Hybrid or not, consumers need common-sense, easy-to-follow advice. John DeCicco of Environmental Defense offers these words: "The only truly sound advice is really quite straightforward: When it comes to selecting a vehicle, simply choose the most fuel-efficient model that meets your needs and fits your budget."

Toyota Prius

More Priuses have been sold than all other hybrids combined—and for good reason. Since the debut of the second generation Prius in 2003 (as a 2004 model), the midsize hatchback sedan has racked up one award after another. More than two years later, it continues to be a red-hot seller, with Toyota and its dealers having trouble keeping up with demand. The Prius instills a cultlike devotion from its drivers. Satisfaction rates, consistently at 98 percent, are unparalleled. Prius owners are already looking twenty years ahead, when they can claim with great pride, "Yes. I drove one of the first Priuses."

The Prius works like a charm, humming along silently in all-electric mode at low speeds, and revving up its 110 combined gas and electric horsepower for a respectable 0-to-60 mph rate of 10.2 seconds. Bean counters argue that the Prius is two to three thousand dollars more than a comparable Camry or Corolla. That's a joke to Prius owners. Those conventional vehicles can't be compared to the Prius in terms of its unique technology and design, and especially in the categories that matter most to the average hybrid buyer—an EPA combined city–highway fuel economy rating of 55 mpg, and 89 percent fewer smog-forming emissions than the average new car.

Honda Civic Hybrid

By all accounts, Honda not only designed the heck out of the 2006 Civic—giving it a daring new style—but they engineered it to the extreme. The Civic Hybrid breaks the 50 mpg mark for both highway and city EPA numbers, and qualifies for Advanced Technology Partial Zero-Emissions status in all 50 states.

How did Honda achieve more power and efficiency, and cleaner emissions, all at once? Honda is on the fourth generation of its integrated engine–motor design. The '06 Civic combines a 1.3-liter, iVTEC 4-cylinder engine with a 20 hp electric motor to deliver a total of 110 hp. The new power train is 20 percent more powerful and 5 percent lighter than the previous model.

The Civic Hybrid, in certain cruising modes, can also deactivate all of its cylinders. During this time, the electric motor alone powers the vehicle. At other stages of acceleration and cruising, Honda's variable-valve system allows cylinders to activate and deactivate for the right mix of performance and efficiency.

Honda Accord Hybrid

Here's the formula for the Honda Accord Hybrid: Take the second best-selling car in the country, offer it with as many luxury features as possible, and soup it up to make it faster than any other family sedan on the market. This approach—using hybrid technology to boost performance and to only moderately improve fuel economy—caught car reviewers and hybrid fans by surprise when the Accord Hybrid was introduced in November 2004. Aren't hybrids supposed to be small, underpowered, econo-boxes with great fuel economy?

One headline read, "Sips Gas. Hauls Ass." Environmentalists pinned the term "muscle hybrid" on the Accord. David Welch of *BusinessWeek*, as if shocked, wrote, "The car bursts onto the road. Yeah, this car—an environmentally friendly and fuel-efficient hybrid—really did burn a little rubber."

Honda was the first to introduce a hybrid in the U.S. market, with the Honda Insight. They were the first to offer a hybrid version of a conventional vehicle with the Honda Civic Hybrid. And suddenly, they were the first to show that a hybrid could offer more performance, more amenities, and better fuel efficiency than other vehicles in its class.

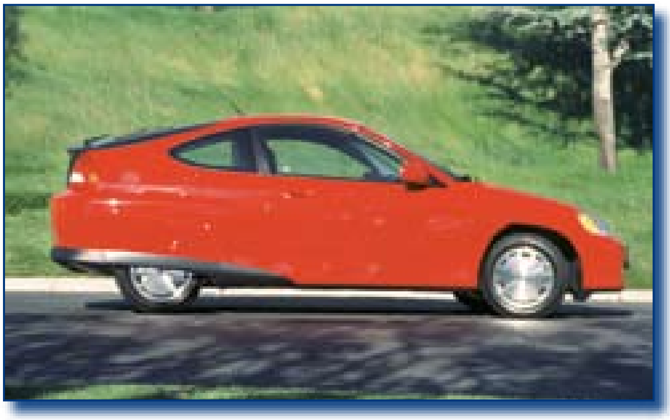
Toyota Camry Hybrid

You'll never get accused of recklessness for buying a Toyota Camry. It's safe, comfortable, dependable, relatively attractive, and altogether predictable. And based on the sales numbers—more than 430,000 sold in the United States in 2005—Americans are happy with a reliable and affordable set of wheels for the family. The Camry has been America's top-selling passenger vehicle for eight of the past nine years. As long as you're being practical, why not invest a few extra dollars for the Camry with a hybrid drive that offers an EPA rating of 40 miles to the gallon, and gives you about 700 miles between visits to the gas station?

In the Toyota Prius, the hybrid system was a bold move into unknown technology. The hybrid option on the Camry seems like a common-sense choice for an era when a single storm—meteorological or political—could send gas prices to US$4.

In the Accord lineup, the hybrid is the fastest and the priciest. The Camry Hybrid is neither. Those dubious honors go to the fully loaded, sporty Camry SE—with a 3.5-liter engine delivering 268 horsepower, a 40 percent jump in acceleration over the 2006 model. The choice between speed and fuel economy is quite clear: Consumers who care about fuel economy can choose between the standard Camry's four-cylinder combined highway–city rating of 28 mpg, the V6's mpg rating of 26, or the hybrid's 40 mpg.

Honda Insight



If you really want to do your part to reduce greenhouse gases and air pollution, ride a bike and take public transportation. The next best thing is to drive the Honda Insight.

Other models may offer luxury features and enhanced performance, but wasn't the point of hybrids supposed to be great gas mileage? If reducing pollution and our foreign oil dependency is the reason you're thinking about a hybrid—and you can live with a two-passenger car—the Insight may be just the ticket.

Released in 2000 as the first hybrid car to hit the mass market, the Honda Insight is the undisputed king of fuel efficiency and low emissions. But grab a new Honda Insight while you can. Honda recently announced that they will stop making the Insight in September. The company sells fewer than 100 Insights per month.

Hybrid vs. Conventional Vehicles, 2006 Models

Vehicle	Version	Annual Emissions (Based on 13,000 Miles)*: NO_X[a] (Lbs.)	CO[b] (Lbs.)	CO_2[c] (Lbs.)	Hydro-carbons[d] (Lbs.)	Particu-lates[d] (Grams)	Gas Mileage (Estimated MPG): City	Hwy.	Base Price (US$)	Electric-Only Mode?
Ford Escape, 2WD	Hybrid	7	144	7,359	5	276	36	31	$27,515	Yes
Ford Escape, 4WD	Hybrid	7	144	7,949	5	276	33	29	29,140	Yes
Ford Escape, 2WD	Gas	9	199–294	10,450	6–8	276	20–22	24–26	19,995	—
Honda Accord	Hybrid	6	146	8,703	4	221	25	34	30,990–32,990	No
Honda Accord	Gas	6–8	146–298	8,930–10,625	4–7	221	20–26	29–34	18,225–29,300	—
Honda Civic sedan	Hybrid	6	146	4,952	4	221	49	51	22,150–23,650	Yes
Honda Civic sedan	Gas	8	204	7,307–7,453	6	221	30	38–40	14,760–20,760	—
Honda Insight, manual	Hybrid	17	219	3,948	6	221	60	66	19,330–20,530	No
Honda Insight, CVT	Hybrid	6	154	4,386	4	221	57	66	21,530	No
No Insight gas version	Gas	—	—	—	—	—	—	—	—	—
Lexus RX 400h, 2WD	Hybrid	8	152	8,086	5	276	33	28	44,660	Yes
Lexus RX 400h, 4WD	Hybrid	8	152	8,499	5	276	31	27	46,060	Yes
Lexus RX 330	Gas	9	199	11,596–12,178	6	276	18–19	24–25	36,370–37,770	—
Mercury Mariner	Hybrid	7	144	7,949	5	276	33	29	29,840	Yes
Mercury Mariner	Gas	9	288–294	10,450–11,983	8	276	19–22	23–26	21,995–27,400	—
Toyota Camry**	Hybrid	6	146	6,321	4	221	40	38	25,900	Yes
Toyota Camry**	Gas	6–17	146–219	8,930–10,762	4–6	221	22–24	31–34	18,270–27,520	—
Toyota Highlander, 2WD	Hybrid	8	152	8,086	5	276	33	28	33,030–37,890	Yes
Toyota Highlander, 4WD	Hybrid	8	152	8,499	5	276	31	27	34,430–39,290	Yes
Toyota Highlander, 2WD	Gas	9–16	199–288	10,292–12,178	6–8	276	18–22	24–27	27,765–30,085	—
Toyota Prius	Hybrid	6	146	4,444	4	221	60	51	21,925	Yes
No Prius gas version	Gas	—	—	—	—	—	—	—	—	—

*Emissions data courtesy of HybridCars.com; **2007 model; [a] Lung Irritant, [b] Poisonous Gas, [c] Greenhouse Gas, [d] Smog

Ford Escape Hybrid / Mercury Mariner Hybrid

The Ford Escape Hybrid had its day in the limelight when it debuted in mid-2004 as the first American-made hybrid and the first SUV hybrid. A SUV that could boast more than 30 mpg was certainly deserving of recognition. Never mind that actual mileage has been running in the mid-20s for many owners, that Ford is only producing 20,000 units, or that the company abandoned its commitment to significantly bump up the fuel economy of its fleet. They were indeed the first to produce an SUV hybrid, and they deserve a pat on the back. And it did win the North American Truck of the Year Award at the 2005 North American International Auto Show in Detroit.

The Escape nudges out the other SUVs' fuel economies by sacrificing performance, but its 155 hp system, while slower than the Toyota Highlander's 268 hp system, has plenty of power for our congested roads. Also, the price tag is likely to be US$5,000 less than a Highlander Hybrid, and US$20,000 less than the Lexus SUV Hybrid. For a few thousand dollars more, you can opt for the upscale version of the Escape Hybrid—the Mercury Mariner Hybrid.

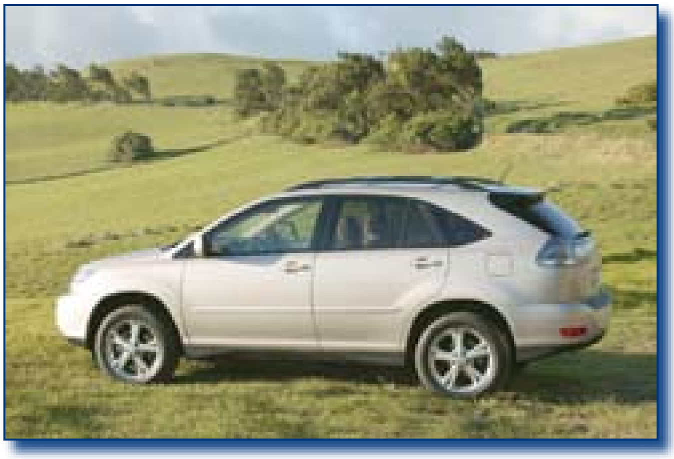
Toyota Highlander

It's not fair to compare a midsize coupe to a midsize SUV, but let's do it anyhow, as a way to establish a point of reference for just how far the hybrid options have come. How does the Highlander Hybrid compare with a Prius? The Prius uses a modest 1.5-liter, four-cylinder, 106-horsepower gas engine versus the Highlander Hybrid's beefy 3.3-liter, six-cylinder, 208 hp gas engine. When combined with the power of the electric motor, the total power of the Highlander is 268, compared to the Prius's 110 hp.

Motor Trend calls the Highlander Hybrid "a bullet." But for some hybrid shoppers, the pride of the Prius's 60 mpg city rating far outweighs the thrill of moving from 0-to-60 in less than 8 seconds in the Highlander Hybrid. A Prius looks and feels like a hybrid. The Prius's unconventional design is carried inside, with its use of a funny-looking key (Toyota calls it a "fob") and a start button. In a Highlander Hybrid, nobody will really know that you're driving a hybrid. The Highlander starts up with a regular old key. The speed and normal-ness of the Highlander should take its appeal beyond the most ardent supporters of hybrid technology.

Lexus RX 400h

Why are thousands of American car buyers plunking down US$50,000 for a luxury hybrid SUV? Because, essentially, it has everything a high-end SUV buyer seeks—rugged exterior, leather-swaddled creature-comfort interior—while delivering a reported 28 mpg on the highway and 30 mpg around town. And with 0-to-60 performance in less than 8 seconds, it should appeal to those who have the occasional urge to merge—on the freeway—with unhybrid-like alacrity.



Denny Clements, Lexus group vice president and general manager, sums it up, saying, "The RX 400h exceeds the expectations of luxury vehicle buyers and establishes a premium market for performance-oriented, fuel-efficient gas-electric hybrids." The fuel economy is a far cry from the upper 40s and 50s of the compact sedan hybrids, but the Lexus SUV hybrid will at least introduce an entirely new segment of drivers to the pleasures of hybrid life. Once this group starts paying attention to their fuel economy, I hope they'll slow down on the road, drive more carefully—and maybe even give up a little size, speed, and luxury for more miles-per-gallon with their next car.

Hybrid Awareness, Hybrid Future

In August 2000, the U.S. Department of Energy asked more than 1,000 Americans to provide the name of a hybrid vehicle. Only 2 percent could correctly identify the models available at that time—the Honda Insight and Toyota Prius. Another 19 percent answered more generically that Honda and Toyota offered hybrids, but 64 percent were entirely stumped.

Five years later, the number of "don't know" answers is only down to 45 percent—which is surprising when you consider how rapidly car buyers have adopted hybrids. Sales in the United States grew from 9,500 in 2000 to more than 205,000 in 2005. And still, more than four in ten Americans can't name a single model.

Market forecasters predict a continued annual doubling of hybrid car sales for the next few years. We could reach the major milestone of one million hybrid cars on American roads somewhere in the 2007 or 2008 time frame. This seems like cause for celebration, until you consider that there are approximately 200 million cars in America today—and more than 700 million vehicles worldwide. If car numbers keep increasing at the present rate, more than one billion cars and trucks will be on the world's roads in twenty years. Vehicles are now driven two trillion miles each year in the United States, and there are more cars than adults.

Nevertheless, with the proven success of the Toyota Prius, which won many accolades in 2004, the hybrid makers are rolling out new models. In 2005, Ford became the first American automaker to join the hybrid market with the introduction of the Escape Hybrid. The 2006 Honda Civic, available as a hybrid (as well as a compressed natural gas vehicle), took *Motor Trend*'s top honors this year, and *Consumer Reports* ranked the Toyota Highlander Hybrid as the best midsize SUV.

This impressive string of accolades—along with rising gas prices—has encouraged nearly every carmaker in the world to join the hybrid bandwagon. By the end of the decade, car buyers may be able to choose from as many as 30 or 40 hybrids.

To Hybrid or Not

Most forecasters peg the hybrid market to remain in the single digits of new car sales. However, these forecasts are the product of an industry that has resisted every innovation to produce cleaner, safer vehicles. Remember, Detroit also fought against seat belts, catalytic converters, and air bags.

The industry has claimed for decades that they lack the technology to produce more fuel-efficient vehicles, and even if they could, the public wouldn't buy them. Hybrids have shattered their tired old arguments. Hybrids have shown that the car-buying public will embrace changes in technology—and in fact pay handsomely for it—if it leads in the right direction.

The number of cars combining gas and electric drivetrains on the road today or in 2010 is less important than the fact that hybrids have served as a wedge to pry open the way auto technology, and cars in general, are viewed. Now, when naysayers put up opposition to new ideas for powering our vehicles—or for that matter, our homes and cities—we can point to the million hybrids on the road as shining examples of what's possible, and hope for a more sustainable future.

Access

Bradley Berman • brad@hybridcars.com • www.hybridcars.com

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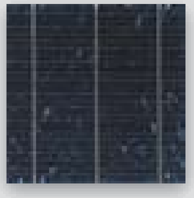

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Gene Foster on his off-grid golf course.

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A Hybrid Solar and Wind System

John Miggins

Gene Foster is a modern-day pioneer, a self-made man who has transformed his 40-acre property in Paris, Arkansas, into a self-sufficient homestead. Over the last nine years, Gene has converted a piece of raw land nestled in the beautiful Arkansas valley to a virtual oasis, complete with a 1,600-square-foot rock home, a 5-acre fish pond, and his own nine-hole golf course.

Gene has been in the machining business as owner of Foster Enterprises for 25 years, a trade that has helped him build and modify his independent energy system. When he took a serious look at his retirement options, he realized that his energy costs for 2004 were more than US$3,500, and increasing every year.

The alarm bells started ringing, and he asked himself, "How can I get a better return on the investment in my new home, and plan for my energy future?" Gene set out to lower his energy bills, which at his rate of consumption would total US$35,000 over ten years. He started researching his options on how to provide the four main elements of his home energy needs—heating, hot water, cooling, and electricity. Here is how he did it.

Conservation

As a first step, Gene set out to reduce his energy demand by insulating his home and shop thoroughly. The original house had wood siding with R-13 insulation. A 1-foot-thick stone facade was added to the home's exterior, with a 1- to 2-inch (2.5–5 cm) gap between the rock and the original siding. Gene then built a large, south-facing screened porch overlooking the pond to manage the afternoon sun's impact on his house, and provide a pleasant place to oversee his property.

He replaced his natural gas-fueled range, cooktop, and clothes dryer with propane appliances that are supplied by a 100-pound (45 kg) propane tank, which usually yields a six-month supply. He continues to use these appliances sparingly along with his microwave, which had its clock disconnected to reduce the phantom load. All the lighting in his home and workshop is either compact fluorescent or tubular fluorescent for higher efficiency. He has three ceiling fans and a 3-ton central air conditioner to cool his home. With the exception of the air conditioner, the electrical needs in the house are relatively modest.

In the 40- by 60-foot (12 x 18 m) workshop, he has a full machine shop with lathe, mill, sharpeners, grinders, air compressors, and other assorted tools. These are used to maintain his golf course, and to fabricate the many innovations he has developed. The shop's electrical load can be large, but most of the time only one device is running. A separate load center in the shop is fed from the main panel at the house. These two AC distribution panels are connected, and now his independent energy system feeds them both. An 18 KW diesel generator is used as a backup power source for battery charging, and to periodically assist large loads like the air conditioner, irrigation pumps, and shop tools.

Gene Foster's large workshop has served as a useful place for fabricating his wind generator tower and PV rack.

This sunroom provides passive heating and daylighting.

Heating & Hot Water

Heating and hot water was the easy part. Gene purchased an outdoor wood-burning furnace from Hardy Manufacturing. The unit provides both heat and hot water to his home and workshop. It works very well, is made of stainless steel, and will burn for 24 hours or more on a single load of logs, which are plentiful around the property. This furnace is extremely efficient and uses an open-loop water heat exchanger that provides ample hot water to two water tanks and also feeds hot water to two water-to-air heaters for the shop.


An outdoor wood-burning furnace provides most of the home's space-heating needs.


This drip oil-assist booster increases heat and reduces the amount of wood needed.


An open-loop heat exchanger provides warm air in the shop.

Gene then designed and installed a drip oil-assist booster that feeds used oil to the heater on a timed basis to boost the heating capacity of the furnace. The unit injects 2 ounces (60 g) of oil at timed intervals, which allows the fire and flame in the firebox to burn hotter and reduces the amount of wood needed by half.

The house is also heated with a large wood-burning fireplace that draws in cool air at the bottom and blows warmed air out at the top. Gene ducted this heated air stream to each room to heat his whole home comfortably. These innovations are simple but very effective.

Cooling

Cooling the house presented the largest load. The 10-year-old, 3-ton air conditioning unit is not efficient (newer models use about half as much energy), and worked the inverters hard when the compressor kicked in. To rectify this, Gene had his air conditioning service technician install a soft-start kit (capacitor) to reduce the compressor's start-up surge.

The inverters can now handle the air conditioner with no problem, but to limit its high energy demand and use, Gene designed and installed a fresh water, open-loop cool water booster. By pumping cool water from the bottom of his 80-foot (24 m) well into an A-coil installed in the indoor blower unit, the home's interior air temperature is significantly reduced. The water is then returned to the top of the well and cycled again. The system is simple and effective for short periods of time.

A hybrid heating system keeps Gene's home at a comfortable temperature.

Electricity

Gene enlisted my company, Harvest Solar & Wind Power, to design and install his independent electricity system. After our first meeting, we realized that he had already taken most of the initial steps toward conservation that we normally recommend. He knew his energy needs, and was perfectly willing to manage them and his energy generation to achieve the goal of energy independence.

Gene wanted multiple charging sources that would allow for some energy production in any weather condition at any time of day. We designed an off-grid hybrid system using solar electricity, a wind generator, and a backup engine generator. Gene has also built a custom microhydroelectric turbine to add to the energy mix.

We chose components carefully to allow for maximum production and flexibility, and to provide for future growth of the system. A 48-volt system was chosen to keep system efficiency high and wiring costs low.

We specified an OutBack power panel with two OutBack VFX3648 inverters and all the options. The panel includes an OutBack MX60 charge controller, the Mate

Author John Miggins shows off the OutBack power center.

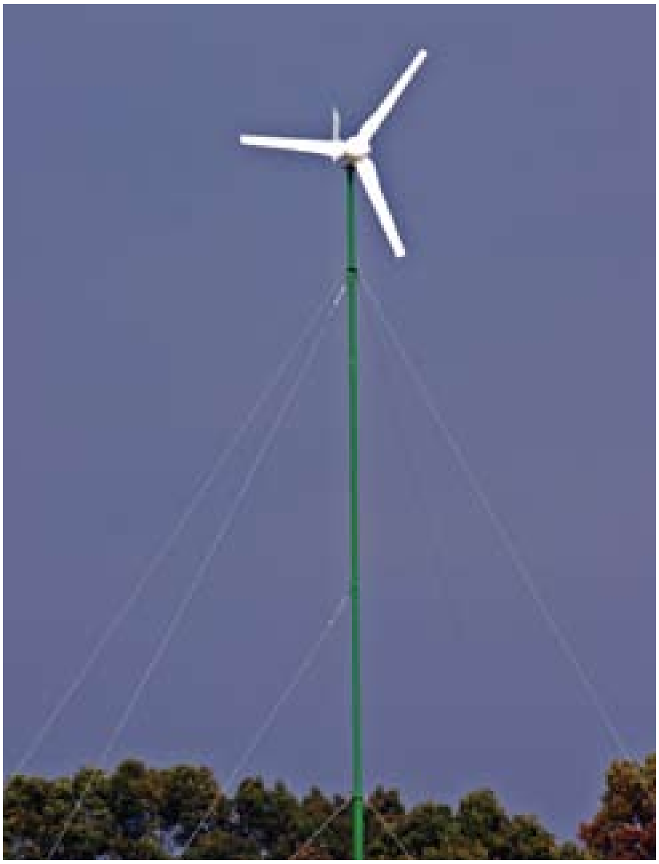
system monitor, and OutBack disconnects all prewired. This UL-approved power panel supplied by Conergy Inc. simplified the installation and can accommodate up to four inverters if needed. Phil Undercuffler at Conergy and Matt Rust at OutBack were very helpful in the design of this panel, and Conergy had it built and shipped in two days!

We selected Surrette S-530 batteries because of their excellent reputation, long life, 10-year warranty, and safe design. The battery bank is made up of three strings of eight batteries, wired in series and parallel for a 48-volt system with about 80 KWH of total capacity (40 KWH usable at 50% DOD). The battery system has worked flawlessly. The batteries are installed next to the power panel in the shop on a custom rack that Gene built, and placed next to the south wall to help keep them warm in the winter.

Photovoltaics

The solar-electric array is made up of 22 Sharp 165-watt modules, wired at 48 volts to provide 3,630 rated watts and about 12 AC KWH per day. At the time, these were the largest panels we could get, and we received excellent service and design assistance from Doug Broach with Carmanah.

The modules were installed on two custom, tracking mounts that Gene built on site. Setting the charge parameters for the OutBack inverters and MX60 was simple and straightforward, given the information from James Surrette at Surrette Batteries and Matt at OutBack. The batteries and inverters have risen to meet any electrical demand that Gene has thrown at them. The ability to recharge the batteries with a strong generator and Gene's willingness to manage his demand are keys to the success of the system.



The African Wind Power turbine is the main power source on days when there's more wind than sun.

Just another sunny day on the course for Gene Foster.

Wind Generator

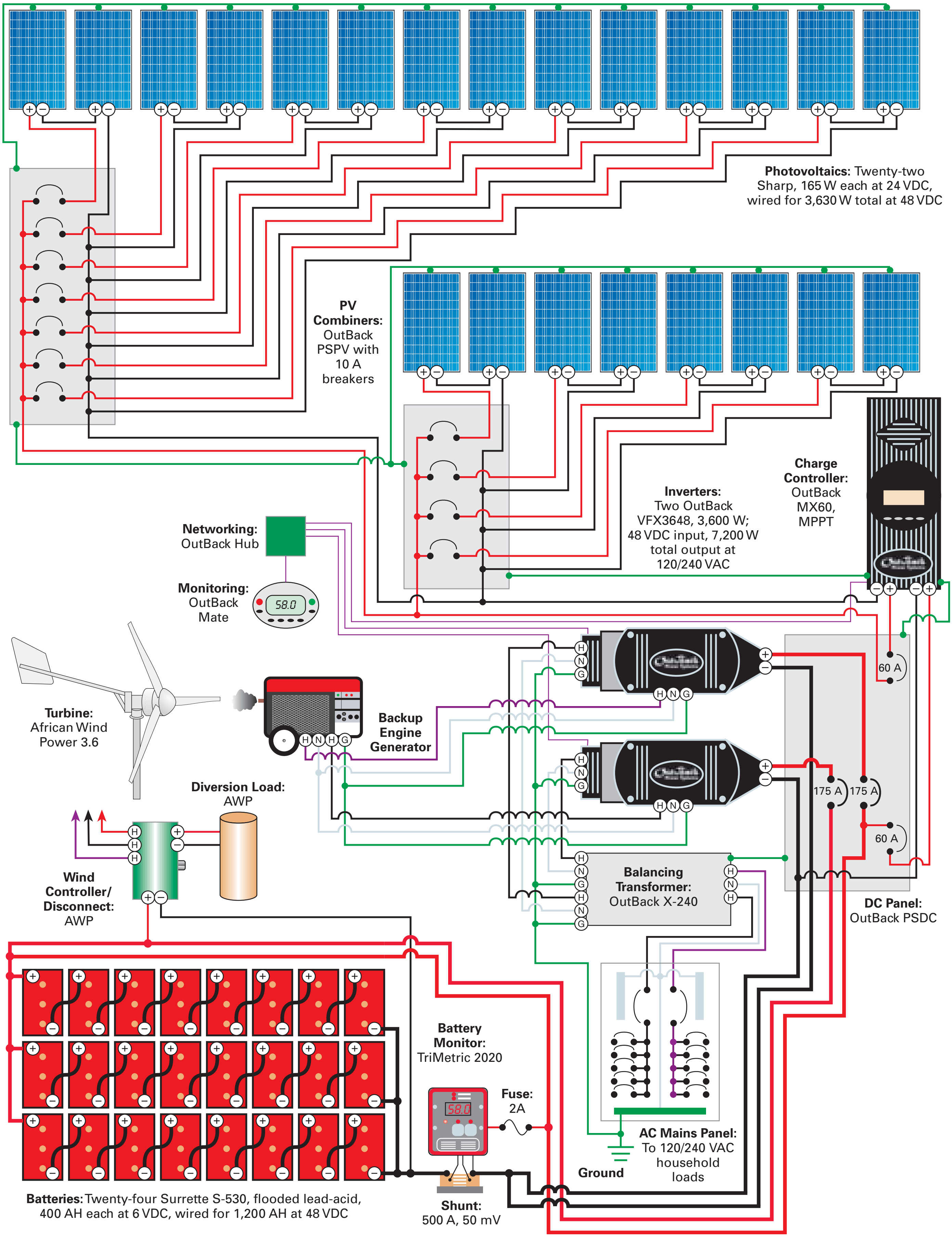
Gene selected the African Wind Power (AWP) 3.6 wind generator with its own controller and air heater dump load. This generator sits on an 80-foot (24 m) tower that Gene designed and built. The tower's design allows him to single-handedly raise and lower the wind generator, another of his engineering feats.

Gene installed the tower and wind generator himself, with buried cables to the power room, where the three-phase wild AC output of the generator is converted to 48 volts DC. The AWP 3.6 is a robust machine that starts generating at about 9 mph (4 m/s), and is a quiet yet reliable addition to the system.

Microhydro

Gene's golf course is small, but the greens require a lot of water, so he created a 5-acre pond. Two 240-volt pumps supply water to each green for an hour each morning in the summer, with ample power and energy from the system.

There is a 10-foot (3 m) drop on one side of the pond where Gene is installing his own microhydroelectric turbine. When the seasons change and the greens need less water, the hydro system will be employed to charge the batteries. In the fall and spring, the creek-fed pond used



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

Tech Specs

Overview

System type: Off-grid, battery-based PV and wind-electric

Location: Paris, Arkansas

Solar resource: 4.5 average daily peak sun-hours

PV production: 360 AC KWH per month

Wind resource: 10 mph (4.5 m/s) average wind speed

Wind production: 160 AC KWH per month

Photovoltaics

Modules: 22 Sharp, 165 W STC, 34.6 Vmp, 24 VDC nominal

Array: 11 two-module series strings, 3,630 W STC total, 69.2 Vmp, 48 VDC nominal

Array installation: Homebuilt trackers

Wind Turbine & Tower

Turbine: African Wind Power (AWP) 3.6

Rotor diameter: 11.8 feet (3.6 m)

Rated energy output: 192 DC KWH per month at 12 mph (5.4 m/s)

Rated peak power output: 1,000 W at 22 mph (9.8 m/s)

Tower: 80-foot guyed, tilt-up, homebuilt

Energy Storage

Batteries: 24 Surrette S-530, 6 VDC nominal, 400 AH at 20-hour rate, flooded lead-acid

Battery bank: 48 VDC nominal, 1,200 AH total

Balance of System

PV charge controller: OutBack MX60, 60 A, MPPT, 48 VDC nominal input voltage, 48 VDC nominal output

Wind turbine charge controller: AWP controller with diversion load

Inverters: Two OutBack VFX3648, 48 VDC nominal input, 120/240 VAC output

System performance metering: TriMetric battery monitor

System Costs

Description	Cost (US$)
22 Sharp 165 W panels	$15,950
OutBack power panel	6,950
Deutz diesel engine generator	6,500
24 Surrette S-530 batteries	5,664
AWP wind generator	3,015
PV rack, homebuilt	2,500
Tower, homebuilt	1,500
Wiring, other	400
Installation	400
Wiring, batteries	360
TriMetric battery monitor	200
OutBack combiner box/wiring	199
Total	$43,638

to run over the spillway. Now Gene will divert this water into the hydro generator for additional charging capability about four months out of the year. When the pond is full enough, the hydro plant will be able to run for 48 hours nonstop.

Diesel Generator

The fuel-fired generator is a new Deutz diesel 18 KW generator that runs on 1/2 gallon (2 l) of fuel per hour at half load, and puts out stable 120/240 volts AC. Gene will have to pay for diesel to run it, but he can buy off-road diesel by the tanker load. This backup generator provides a nice buffer should his system require more input. The engine generator's AC output feeds into the AC inputs of the OutBack power panel and is immediately available for direct use, to charge batteries, or both.

Pulling the Plug

After the system was installed and tested, Gene pulled the plug on his utility service. In many cases, this wouldn't make economic or environmental sense, but the local utility is not supportive of grid-tied systems. They would have paid a low rate for Gene's surplus electricity, while requiring him to spend at least US$2,500 to meet their equipment standards. Gene enjoys both the independence and the responsibility of having a stand-alone renewable energy system.

The system is designed with the ability to harvest the energy abundant around us in multiple ways and allows Gene to live off the land, while still enjoying all the comforts of a modern home. Having an independent energy system is a dream of many that is now a reality and a source of pride for this Arkansas homeowner. Having plenty of golfing buddies to help enjoy it with makes it that much more fun.

Access

John Miggins, Harvest Solar & Wind Power, 1571 E. 22 Pl., Tulsa, OK 74114 • 877-743-2299 or 918-743-2299 • Fax: 877-743-2299 or 918-743-2299 • jmiggins@cox.net • www.harvest-energy.com • System designer & integrator

Gene Foster, Foster Enterprises, 8591 W. State Hwy 22, Paris, AR 72855 • 479-635-2651 • Owner & system designer

Abundant Renewable Energy (ARE) • 503-538-8298 • www.abundantre.com • AWP 3.6 wind generator

Bogart Engineering • 831-338-0616 • www.bogartengineering.com • TriMetric battery monitor

Carmanah • 800-671-0169 or 801-501-9353 • www.carmanah.com • PVs & design support

Conergy • 888-396-6611 or 505-473-3800 • www.conergy.us • Design & engineering support

Deutz Corp. • 770-564-7100• www.deutzamericas.com • Diesel engine generator

Hardy Manufacturing Co. Inc. • 800-5-Hardy-5 or 601-656-5866 • www.hardyheater.com • Outdoor wood-burning furnace

OutBack Power Systems • 360-435-6030 • www.outbackpower.com • Power panel, inverter, etc.

Sharp Solar • 800-237-4277 • www.solar.sharpusa.com • PVs

Surrette Battery Co. Ltd. • 800-681-9914 or 902-597-3767 • www.surrette.com • Batteries

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Hiring a PV Pro

Laurie Stone

With 20 years of experience, licensed solar-electric installer Bob-O Schultze is a pro at installing both large and small systems.

Finding a solar-electric system installer is like choosing a long distance phone company—it can be as simple or as complicated as you make it. You can let your fingers do the walking and choose the first one you find in your local yellow pages, or you can do additional research and find an installer that best meets your needs. Mail-order companies, large discount warehouses, small mom-and-pop businesses, and large corporations all sell and install renewable energy (RE) systems. As the number of dealers, distributors, and installers grows, being an informed consumer is increasingly important. And just like buying a car or a computer, you'll want to be sure that the person designing and installing your new system has the expertise to provide you with an efficient, safe, and reliable system.

Think Local

To locate an installer near you, you can always inquire with your local solar organization. The American Solar Energy Society (ASES) has chapters in 34 states, and your local chapter can provide you with a list of installers and dealers (see Access). ASES also cosponsors the "Find Solar" Web site at www.findsolar.com, where you can find detailed listings of PV pros across the United States and Canada. If you live in the Heartland, the Midwest Renewable Energy Association offers a great resource for finding an installer. You can also check out *Home Power*'s Web site for a searchable database of RE dealers and installers, or look in the Installers Directory at the back of each issue.

Most of us want the best product for the least cost. Shopping by price is important, especially if you are on a tight budget, but there are also other factors to consider. Following is a list of some of the issues to think about when selecting an installer.

Courtesy Electron Connection, www.electronconnection.com

Professional credentials. Organizations are now certifying installers by a set of standards, and asking for an installer's credentials can give you an idea of these qualifications. The North American Board of Certified Energy Practitioners (NABCEP) offers PV certification on two levels—an Entry Level Certificate of Knowledge, and a PV Installer Certification. According to NABCEP, "Certification is not intended to prevent qualified individuals from installing PV systems…it is meant to provide a set of national standards by which PV installers with skills and experience can distinguish themselves."

That said, many seasoned pros who have been in the business for years don't see the need for additional certification. They may not choose to dedicate the extra time or expense to become NABCEP certified.

Electrical License. If you contract with an installer who doesn't have an electrical license, you or your installer will also need to hire a licensed electrician to obtain the permit, supervise the job, and do the final AC hookups. Regulations for residential electrical work vary from state to state, so be sure to check with your local building department prior to system installation. Your installer should have a good working relationship with the local electrical inspector. Also, if you expect to take advantage of financial incentives, be aware that most states won't provide rebates if the installer isn't licensed.

Bonded & Insured. It's always a good idea to check if your installer has liability insurance. This insurance coverage protects you against any installation mishaps—if the installer's work damages your house during or after the installation. Some installers advertise that they are "bonded" as well. This guarantees that the contractor will meet his or her obligations in a satisfactory manner. Failure to do so results in the bonding company paying you compensation. However, being bonded is expensive, so if you want an installer who is both bonded and insured, you'll probably have to forego a mom-and-pop operation for a large installation company.

Training. How recently and where has your installer been educated and trained? Find out if the installer has kept up-to-date with training courses on the specific products he or she sells. Many companies that manufacture and distribute RE products offer training, enabling installers to stay current on new product developments.

Experience. Don't be shy about asking about an installer's experience. Every installation is different, so the more installations an installer has handled, the better. Find out how many systems similar to yours the installer has designed and installed. Plus, there are always new products entering the market, and new regulations to deal with. An installer who has completed several recent installations will probably be up-to-date on the newest products and the latest code issues.

Variety & Quality of Products. The variety of products an installer carries may or may not be important to you. But the more brands an installer carries, the more likely he or she will be to have one that fits your application. However, if the installer only carries a couple of brands and those brands work for your system, variety is not important.

While the variety of products might not be crucial, the *quality* always is. Do some research on the inverter, controller, and other balance of system components that your installer suggests. Do the products meet industry standards? All components used in your system should be listed by Underwriters Laboratory (UL) or an equivalent testing agency. UL is a nonprofit product testing and certification organization that verifies electrical products are safe for their intended use. ETL Semko and the Canadian Standards Association (CSA) provide similar approvals. Checking products to make sure they are UL, ETL, or CSA approved is one way to make sure the equipment used for your installation is reliable and safe.

What kinds of warranties come with the products that your installer carries? Also, how long have the equipment manufacturers been in the PV industry? Long warranties are meaningless if the manufacturers aren't around in five years. If you know of other people who have used these products, ask for their feedback: Are they satisfied? Have they had problems?

Service Agreements & Performance Guarantees. Installers should provide you with some kind of optional service agreement. If problems arise with your system,

Neal Mock from Solar Wind Works wraps up another system installation.

Courtesy Solar Wind Works, www.solarwindworks.com

10 Things Your Installer (Probably) Won't Do For You

Your installer should provide you with a safe, reliable, working PV system. He or she should also be prepared to perform maintenance and repair visits if that's stipulated in your contract. However, be prepared to do some things for yourself. Here are ten things your installer probably will not do for you.

1 Analyze your energy needs. While it is up to the installer to size your system to meet your needs, it is up to *you* to tell him or her what your needs are. Your installer will not know how often your lights are on each night, how many hours you spend watching TV, or how many loads of laundry you do each day. If you're having a stand-alone system installed, it is especially important to tell your installer how much energy you use and when you typically use it, so that he or she can design a system accordingly. If you've chosen a grid-tied PV system, your installer will examine your previous year's electrical bills to help determine the appropriate system size.

Courtesy Electron Connection, www.electronconnection.com

2 Install equipment that you provide. Some installers may agree to install equipment that you purchased from another dealer, catalog, or online store, but most installers want to provide you with the equipment themselves. This offers them the ability to match the right components and hardware to your particular job, and ensures familiarity with the components to be installed. Be aware of this before purchasing a "great" deal online.

3 Let you help install the equipment. Many homeowners want to help with some of the installation, either to keep costs down or just because it's satisfying to have some hands-on participation. However, understand that many installers are reluctant to have your help. First, you may impede the installation if the installer has to stop frequently to answer your questions. And, more importantly, the installer's insurance may not cover you if you are injured as a result of lending a hand.

If you have your heart set on helping, be honest about your technical knowledge and skills with the installer, and work out the details of what your contribution will be beforehand. For example, a good way to save money without stepping on the installer's toes is to do any excavation work yourself.

4 Maintain your batteries. For battery-based systems, some installers will offer a maintenance contract and will visit on a regular basis to check your system's batteries. However, batteries need occasional equalizing and, in many cases, regular watering. If you do not have a maintenance contract for that, then it's imperative for the life of your batteries that you do it yourself.

5 Adjust arrays seasonally. If you don't have a tracker for your PV modules, they are most likely on a fixed mount that is set for optimal year-round performance. But some systems are designed with adjustable mounts, which enable you to get the most out of your PV system each season by adjusting the tilt angle of your array. Don't expect your installer to do it, unless you have this responsibility written into the contract.

6 Install and maintain an engine generator. If you have a stand-alone system, you most likely will have a backup engine generator. From time to time, it will need maintenance and repair. Not all PV installers are familiar and knowledgeable about repairing generators. Ask about your installer's expertise and willingness to troubleshoot this part of the system, or hire someone who has experience with generators.

7 Read the owner's manuals for you. If you really want to understand your system and each component, which is highly recommended, read the owner's manuals!

8 Be on call to address maintenance and service issues. Even with a contract, your installer may not be able to drop everything to help you exactly when you need it. Thus the importance of reading the owner's manuals, and for taking good notes when the installer discusses maintenance issues with you. It pays to learn how to troubleshoot and fix small issues. Jeff Tobe, PV installer for SEI, likens this to owning a new car. "If it gets a flat tire and you don't know how to change it, you don't expect the dealer to come out and perform this task—even though you paid them thousands of dollars for the car."

9 Manage loads to ensure battery power. Based on your input, your installer should be able to design a system that meets your energy needs. However, if you have a stand-alone system, your installer won't be there to warn you to turn off your TV or delay doing a load of laundry because you'll discharge your batteries too deeply. Household energy management is up to you.

10 Make the sun shine during cloudy weather. Although most installers probably wish they could, this one's out of everyone's hands.

what services will the installer provide and for how long? Will the installer be readily available to troubleshoot and fix problems? If something goes wrong, who is responsible for repair or replacement costs? Who is responsible for maintaining the system? If you are responsible, what kind of training will the installer provide? Will basic system safety issues be explained?

Although service or maintenance agreements have not been standardized throughout the industry, many installers will agree to a site visit at least once a year to make sure the system is performing satisfactorily. For the early years of a system's operation, consider buying a service contract.

References. Contact an installer's former clients to find out if the installer was knowledgeable, easy to work with, and took the time to explain the system's operation. Also find out if their systems are working well, if there have been any problems, and, if so, if the installer returned to fix them. Ask for an installer's business references, and check them, especially if the company's reputation is unknown.

The Final Call

"Homeowners planning to be their own electric utility company," says Solar Energy International Executive Director Johnny Weiss, "should take that responsibility seriously and learn the basic safe operation and proper maintenance of their systems."

While the installer is sizing up the system design, you should be sizing up the installer. Online and mail-order suppliers who never visit the installation site may have difficulty recommending the most appropriate equipment. A comprehensive, on-site solar and load analysis and two-way interview can help ensure a thoughtfully designed and well-planned installation.

Access

Laurie Stone, Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org

Installer Listings:

American Solar Energy Society • 303-443-3130 • www.ases.org

Find Solar • www.findsolar.com

Midwest Renewable Energy Association • 715-592-6595 • www.the-mrea.org

NABCEP • 518-899-8186 • www.nabcep.org

Product Testing & Certification Agencies:

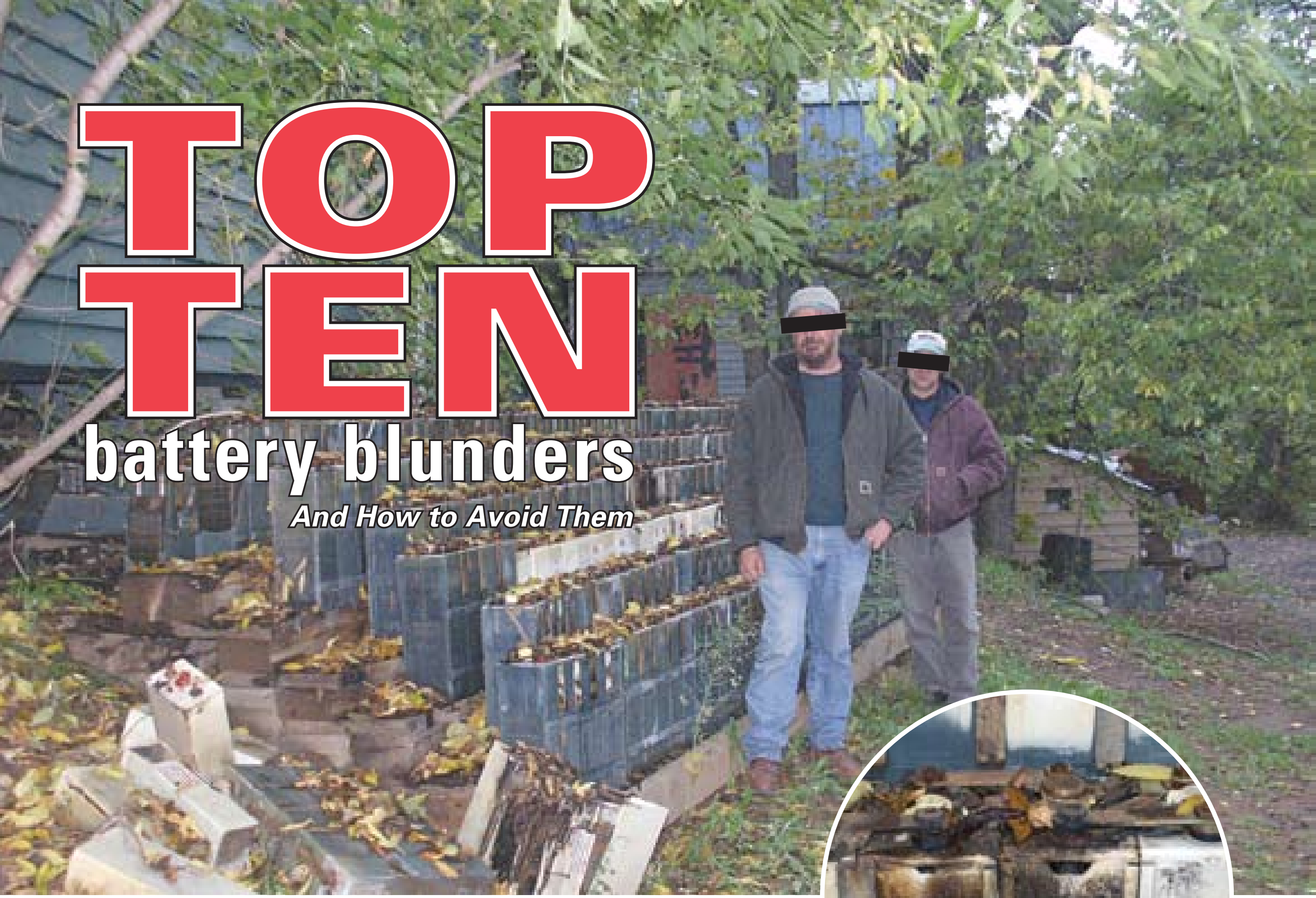
Canadian Standards Association • 800-463-6727 or 416-747-4000 • www.csa.ca

Intertek ETL Semko • www.intertek-etlsemko.com

Underwriters Laboratories Inc. • 847-272-8800 • www.ul.com

TOP TEN battery blunders

And How to Avoid Them



Above: Big battery, big mess. Don't try this at home.
Right: These batteries have definitely seen better days.

Windy Dankoff

Batteries allow us to store our renewable energy (RE) for times when the sun isn't shining and the wind isn't blowing. They are often called the "weakest link" in renewable electricity systems, but battery problems nearly always are the result of bad equipment choices, installation errors, and lack of attention—the human factor!

In my 27 years as a system supplier, I have seen serious battery-related mistakes made repeatedly, by amateurs and professionals alike (and I've made a few myself). The results can be expensive, hazardous, and damaging to the reputation of renewable energy. That's why I am presenting these classic blunders, and their ready solutions. High-quality batteries can last ten to twenty years, but they can die in one or two years if abused.

Nearly all battery-based RE systems use lead-acid batteries. So this article applies only to them (not to other battery chemistries). It applies to batteries charged by PVs, wind, microhydro, and engine generators, the utility grid, or any combination of sources. It applies to off-grid independent systems and also to grid-tied systems with battery backup.

BLUNDER #1

Wrong Battery Type

Batteries are built with a variety of structures and materials, according to the application. If you choose the wrong type, you will get poor longevity.

RE applications require batteries to discharge to below 50 percent of their storage capacity, repeatedly. This is called "deep cycling." A full-time, off-grid home system will typically experience 50 to 100 cycles per year at 30 to 80 percent depth-of-discharge. Always use high quality, deep-cycle batteries in RE applications. Engine-starting (car or truck) batteries are designed for quick, high-power bursts, and will survive only a few deep cycles.

The batteries used in grid-tied, emergency backup (standby) systems will only be deep cycled occasionally when there is a utility outage. Periodically, flooded, deep-cycle batteries need to be actively charged to mix the electrolyte. This prevents stratification of the solution. Because battery cycling/active charging may be very infrequent in standby applications, it's best to use batteries that are specifically designed for emergency standby or float service. They might not be good for hundreds of cycles, but they will stay in working order through years of light usage.

Another distinction is between "sealed" (maintenance-free) and "flooded" (liquid-filled) batteries. Most deep-cycle batteries are flooded. They require occasional watering, but tend to last the longest. Emergency standby batteries are often sealed, and they require no regular maintenance. Deep-cycle, sealed batteries are sometimes chosen because they eliminate need for a ventilated space and for easy access. Sealed absorbed glass mat (AGM) batteries are designed for float applications, and are a great choice for grid-tied PV systems that include battery backup. They typically cost up to twice as much as flooded batteries, and require more careful recharging regimens, but are the best battery type for standby applications.

Starting batteries work great in your car, but will quickly fail if used in deep-cycle applications.

BLUNDER #2

Improper Size

To design a stand-alone renewable energy system, you first establish an "energy budget"—the number of watt-hours you will consume per day. Next, you need to determine how many days of stored energy (autonomy) is required. This variable can range between three and six days (or more) depending on your average daily electrical consumption, the output of the RE charging sources and their seasonal availability, and your willingness to use a backup engine generator.

Most home systems grow larger over time. Loads are added, a PV array is enlarged, but a battery bank cannot be readily expanded. Batteries like to work as a matched set. After about a year, it is unwise to add new batteries to an established bank. If you foresee growth in your system, it is best to start with a battery set that is larger than you need. But be sure you have sufficient charging capability, or the battery bank will be chronically undercharged, which will lead to sulfation and premature failure.

A large battery bank requires a large charging source.

BLUNDER #3

Improper Watering

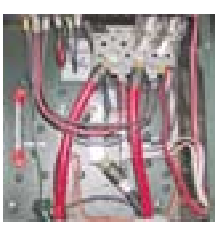
Flooded batteries require the addition of distilled water every two to six months depending on battery type, battery temperature, and on the charge controller settings and system usage. Some people forget to water their batteries. The photo at right shows a system that was ignored for more than two years. The low fluid level caused excessive gassing, and the plates to warp, short out, and spark, ultimately igniting an explosion.

But don't overfill your batteries, either. There is no need to fill them more frequently than required to keep the plates submerged. Fill them only to the level recommended by the manufacturer. Otherwise, during final charging, bubbles will cause excessive spatter and possible overflow, leading to corrosion of the battery terminals and wiring. Though an additional expense, a battery watering system simplifies battery watering.

An extreme result of battery neglect.

BLUNDER #4

Many Small Batteries in Parallel Strings



Use bus bars to parallel multiple series strings.

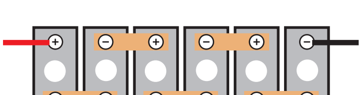
The ideal battery bank also is the simplest, consisting of a single series string of cells that are sized for the job. This design minimizes maintenance and the possibility of random manufacturing defects. Suppose you require a 700-amp-hour (AH) bank. You can approximate that with a single string of 700 AH industrial-size batteries, or two parallel strings of 350 AH (L-16 style) batteries, or three strings of 220 AH (golf cart) batteries. The diagram below shows these three variations.

A common blunder is to buy the smaller batteries because that approach is less expensive up front. The problem is that when current splits between parallel strings, it's never exactly equal. Often, a slightly weak cell or terminal corrosion will cause a whole battery string to receive less charge. It will degrade and fail long before other parallel strings. And because partial replacement aggravates inequalities, the only practical solution is to replace the entire battery bank. One way to reduce or avoid parallel battery strings is to use the highest DC voltage standard that is practical. The same batteries that would form two strings at 24 V can be wired all in one string for a 48 V system (now a common standard). The quantity of energy storage is the same, but the layout is simpler and the current at critical junctures is cut in half.

If you must have multiple battery strings, avoid stacking cable lugs at the battery terminals to make parallel connections. Instead, bring wires separately from each string to two bus bars outside the battery box. This reduces corrosion potential and helps create electrical symmetry.

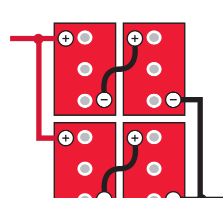
Single String

Large 2-volt cells wired in a single "string"—literally, one big battery.



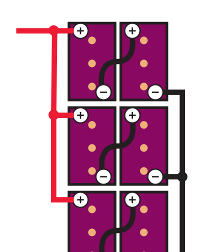
Two Parallel Strings

Medium-size batteries, two strings in parallel. Same amount of lead, equal energy storage.



Three Parallel Strings

Smaller batteries, three strings in parallel. Again, equal energy storage, but much more to go wrong.



BLUNDER #5

Failure to Prevent Corrosion

The fluid in flooded batteries gasses (bubbles) during the final stage of charging. When using flooded batteries, a trace of acid mist escapes and accumulates on the battery tops. This can cause terminal assemblies to corrode, especially any exposed copper, which causes resistance to electrical current and potential hazards. It's an ugly nuisance, but it's simple to prevent.

The best prevention is to apply a suitable sealant to all of the metal parts of the terminals before assembly. Completely coat battery terminals, wire lugs, and nuts and bolts individually. If the sealant is applied after assembly, voids will remain, acid spatter will enter, and corrosion will appear. Special products are sold to protect terminals, but many installers prefer petroleum jelly. It will not inhibit electrical contact. Apply a thin coating with your fingers, and it won't look sloppy.

Exposed wire at a terminal lug should be sealed, using either adhesive-lined, heat-shrink tubing or carefully applied tape. You can also seal an end of stranded wire by warming it gently, and dipping it in petroleum jelly, which will melt and wick into the wire. Or, you can solder the lugs. Whatever the method, these connections must be very strong mechanically. Batteries protected this way show very little corrosion, even after many years.

It's also important to keep battery tops clean of acid spatter and dust. This helps prevent corrosion and stray current across battery tops. Keeping battery tops clean is easy if you keep up on the job. A good habit to get into is to wipe the tops of the batteries with a rag or paper towels moistened with distilled water each time you water the batteries. Do not apply baking soda to the battery tops, since it might enter the batteries, neutralizing some of the electrolyte.

Notice the parallel connections on the left side of the photo—the worst corrosion is at these stacked cable lugs. Batteries with corroded terminals will receive less charge, and will fail early.

BLUNDER #6

Lack of a Protective Environment

Lead-acid batteries temporarily lose approximately 20 percent of their effective capacity when their temperature falls to 30°F (-1°C). This is compared to their rated capacity at a standard temperature of 77°F (25°C). At higher temperatures, their rate of permanent degradation increases. So it is desirable to protect batteries from temperature extremes. Where low temperatures cannot be avoided, buy a larger battery bank to compensate for their reduced capacity in the winter. Avoid direct radiant heat sources that will cause some cells to get warmer than others. The 77°F temperature standard is not sacred, it is simply the standard for the measurement of capacity. An ideal range is between 50 and 85°F (10–29°C).

Arrange batteries so they all stay at the same temperature. If they are against an exterior wall, insulate the wall and leave room for air to circulate. Leave air gaps of about 1/2 inch (13 mm) between batteries, so those in the middle don't get warmer than the others. The enclosure should keep the batteries clean and dry, but a minimum of ventilation is required by the *National Electrical Code*, Article 480.9(A).

A battery enclosure must allow easy access for maintenance, especially for flooded batteries. Do not install any switches, breakers, or other spark-producing devices in the enclosure. They may ignite an explosion.

A beautifully installed 48 V battery bank—sixteen 6 V batteries connected in two strings of eight. These big Surrette batteries have two holes on each terminal, so cable lugs don't have to be stacked. The peaked battery enclosure allows for excellent hydrogen venting.

BLUNDER #7

Lack of Proper Charge Control

Proper controller settings are critical for battery longevity.

When installing new charge controllers or inverters in your system, make sure to program the appropriate charge setpoints for your specific battery type. Battery-based PV systems will usually have a solar charge controller and an AC battery charger, for use with an engine generator or the grid. The AC charger will typically be built into your inverter. Voltage settings appropriate for your type of battery must be programmed into these devices. If incorrect charge setpoints are chosen, sealed batteries can be overcharged and lose their internal moisture. Flooded batteries will be deprived of a full finish charge and will deteriorate if charge setpoints are too low.

When batteries are cold, they require an increase in the maximum charge voltage to reach full charge. When they are warm, they require a reduction in the voltage limit to prevent overcharge. Choose a charge controller and inverter/charger for your system that includes temperature compensation. To use it, you must have a temperature sensor located at the batteries. You may need a temperature sensor for each charging device (including the inverter), but networked systems communicate the temperature from a single sensor to all charging components. Some small charge controllers have temperature sensing built in. In that case, be sure the controller is located where its temperature is similar to that of the batteries. Otherwise, it will be "fooled" into setting improper charge limits.

BLUNDER #8

Lack of Monitoring Devices

Battery management is sometimes called a "black art." That's true only if the user (or supplier) is in the dark. Have you ever driven a car without a fuel gauge? It can be frustrating! Yet, many battery systems don't have an equivalent device to show the state of charge (SOC), the level of stored energy.

Metering is not just bells and whistles. It provides crucial information for battery management, which in turn significantly increases battery longevity. Use a digital monitor, like the TriMetric (Bogart Engineering), IPN-ProRemote (Blue Sky Energy), or XBM battery monitor (Xantrex). These devices keep track of accumulated amp-hours and display the charge status of the battery bank. They also display other data that can be useful for maintenance and troubleshooting.

Install your monitoring device where it can be seen easily—in a central place in your home. Be sure the device is programmed properly, based on the parameters of your system. This needs to be done just once, during meter installation.

Two examples of modern battery monitors (amp-hour meters).

BLUNDER #9

Improper Charging

The surest way to ruin batteries within a year or two is to keep them at a low state of charge (SOC) for weeks at a time. Active battery material will crystallize, covering the plates, which will become permanently inert. We call this "sulfation." Ideally, batteries should receive a 100 percent full charge about once a week for good longevity, and more frequently is better. If this takes a full day of backup charging with a generator, do it! Use your monitoring system to know when full SOC is reached. If you don't have an amp-hour meter, watch for the voltage to reach maximum and the charge current to drop to a low level. This means the batteries are unable to accept much more energy, and are accepting only a "finish" charge.

In winter, some people run their backup generator for an hour a day—just enough to prevent the system from shutting down. Bad idea! It may be better to run it for ten hours, once a week, or whatever it takes to fully charge the batteries, instead of partially charging them more frequently.

Finish-charging a battery bank with an engine generator is an inefficient use of fuel, and results in extremely long generator run times. As a result, generators are typically shut down once the absorption charging stage is finished. But at this point in the charging process, the battery bank will only be at about 85 percent SOC. Since regular, full battery charging is important for battery longevity, make sure that your RE sources are topping off the battery bank after the generator has done the bulk of the charging. Relying on your PV system to provide the finish charge may be difficult during winter months. Another option is to set the inverter–charger to equalizing mode (see below) during generator charging about once a month to ensure that the battery bank is getting fully recharged.

The extreme of undercharging is called "overdischarging." Voltage should never, and I mean never, be drawn below about 11 V (for a 12 V system), or 22 V (24 V system), etc. System controls and inverters usually include a "low voltage disconnect" (LVD) function. If you have DC loads connected directly to the batteries without LVD, you are asking for trouble. It's better to lose power than to squeeze out another watt-hour and damage your batteries. Metering is vital here, because if you wait for the inverter to shut down or the lights to go dim, it's already too late—batteries will likely have lost a portion of their capacity and life expectancy.

Finally, flooded batteries need to be equalized at least four times a year. Exactly how often depends on several factors, including the size of the battery bank in relation to your charging sources and the average depth of discharge during cycling. During normal battery discharging/charging, the individual cells of each battery will stray from a common and consistent cell voltage. Equalization can be thought of as a controlled overcharge of the battery bank that serves to both equalize cell voltage, and provide an aggressive and necessary mixing of the battery electrolyte. Equalization charging can be done with your PV system if your array is large enough, or with an engine generator or the grid. Most PV charge controllers and inverter–chargers have battery equalization functions.

BLUNDER #10

Exceeding Your Energy Budget

If you remove more energy from your battery bank than you put in, your batteries will suffer. It's not the batteries' fault, yet this is the most frequent cause of complaints about batteries "not holding a charge."

Here is one common scenario: A well-meaning appliance seller or mechanical contractor sells you a device that uses "very little electricity." Ha! They don't know about the initial expense of solar electricity. For example, about US$3 will buy you about 40 KWH per month of grid electricity. But adding more PV and battery storage to meet this load could mean an investment of several thousand dollars! Or, without upgrading your system, this would require frequent generator backup (especially in winter). The same blunder also happens when a resident decides it's trivial to leave a coffee maker or large TV on all day. Even low power loads will add up if they're running 24/7. When people don't accept this reality, they overdraw their energy account, and often blame the batteries.

Warning!

Electrolyte in flooded lead-acid batteries is an acid solution. It will burn eyes and skin, and eat holes in clothing. When working around batteries, wear goggles, gloves, and old clothes. Keep baking soda at hand to neutralize acid spills, but never allow any of this alkaline solution to get into the battery. This will diminish the strength of the acid and reduce the battery's capacity.

Gassing (bubbling) of hydrogen and oxygen is a normal occurrence, especially during final, or heavy, charging. This gas is potentially explosive, so keep sparks or flames away from batteries.

Batteries can produce thousands of amps if a direct short occurs. Be very careful when working with metal tools around battery terminals. If you do not feel competent to install or maintain your battery bank, do not hesitate to hire an experienced professional.

Love Your Batteries!

If I had more pages, and I could show the Top 40 blunders, from transportation nightmares to eye injuries to divorce. The lesson: Accept professional advice and service.

Lead-acid batteries are an old but durable technology. They are about 80 percent efficient at releasing stored energy—few high-tech storage systems come close to that efficiency—and they rarely fail suddenly. With good management, you'll know when to replace them before they let you down. And even then, they are fully recyclable. Give your batteries what they need, and your batteries will do the same for you.

Access

Windy Dankoff • windy.hp@mac.com

Other Resources:

Frequently asked questions and answers about batteries • www.batteryfaq.org

"Batteries: How to Keep Them Alive for Years & Years…" by Windy Dankoff in *HP69*

"What is a Charge Controller?" by Windy Dankoff in *HP72*

Using the TriMetric (or other battery system monitor) to Maintain Your Battery System • www.bogartengineering.com/UsingTriMetMaintain.pdf

Thanks for contributions and photos from: Allan Sindelar & Mark Drummond, Positive Energy, Santa Fe, NM; Nick Lucchese, Sierra Solar, Grass Valley, CA; Roy Butler, Four Winds Renewable Energy, Arkport, NY; Ray Walters, SolarRay, Taos, NM; Tom Elliot's Alternative Energy Information Center, Cover Mountain Ranch, CO; Matt Lafferty, Universal Energies Inst., San Francisco, CA; Jamie Surrette, Surrette Battery Co. Ltd., Springhill, NS, Canada; Joseph Marino, DC Power Products, Healdsburg, CA; Phil Undercuffler, Conergy Inc., Santa Fe, NM; Todd Cory, Mt. Shasta Energy Services, Mt. Shasta, CA; Richard Perez & Joe Schwartz, *Home Power* magazine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AEE Solar
FOUR STAR SOLAR
fourstarsolar.com
Sun Pumps

Datalogging Lessons

John Lyons

The author downloads performance data from a portable solar-electric system on the McMurdo Ice Shelf in Antarctica.

Using datalogging systems to measure the performance of renewable energy (RE) systems over time can yield critical information for users and designers. Whether you are trying to optimize your energy use or decide on the best way to enlarge your system, datalogging can help by identifying how much energy you are collecting and using, and at what times.

The problem is that some datalogging systems can cost as much as the RE system itself. But I've developed an inexpensive approach for datalogging small RE systems. The final cost of these setups can be less than US$220, far below any equivalent on the market.

Joe Yarkin, an RE specialist, and I, a field science technician, became interested in RE datalogging while designing portable solar-electric (photovolatic; PV) systems for use in remote areas of Antarctica. These systems are cleaner and safer alternatives to small, fossil-fueled generators, and we needed to gather data on their performance to evaluate system size, load size and usage timing, panel orientation, and component operation.

Paired with a customized suite of sensors, a tiny datalogger like this HOBO H8 becomes a powerful tool for data gathering.

Datalogging Basics

A typical datalogging system includes a recording device and a suite of sensors that convert measurements such as current, voltage, and temperature into small direct current (DC) voltages readable by the recording device. Typical dataloggers can only read a limited range of DC voltages, so a complete datalogging system requires sensors that use a calibrated scaling factor to reduce the measured value to a recordable voltage within the datalogger's range. When the users download the data from the recording device, they convert the recorded voltages back into the measured value using the same calibrated scaling factor.

Building an entire datalogging system from scratch would be very difficult due to the complexity of the datalogger itself, so we decided to purchase a commercially available datalogger and then custom-build our own suite of sensors. We found that the available dataloggers varied in their measurement range, accuracy, memory capacity, power supply, and price.

For our system, we chose the Onset Computer Corporation's HOBO H8 series datalogger because it is small and inexpensive, and can store more than 32,000 measurements. The HOBO can simultaneously measure and record four separate DC voltages ranging from 0 to 2.5 volts (V), at time intervals of 0.5 seconds to 9 hours. Although the HOBO requires a computer connection for configuring and downloading, it does not require any external computer or power connections when it is logging data. Users communicate with the HOBO through a Windows- or Macintosh-based computer that is running a simple interface program supplied by the manufacturer.

The major challenge in building our datalogging system was finding sensors that would convert typical RE currents and voltages into the small DC voltages that the HOBO can read. Although sensors for measuring alternating current (AC) and temperature were available from Onset, the lack of sensors for DC amperage above 20 milliamps (mA) or voltages above 2.5 V led us to develop several of our own sensors.

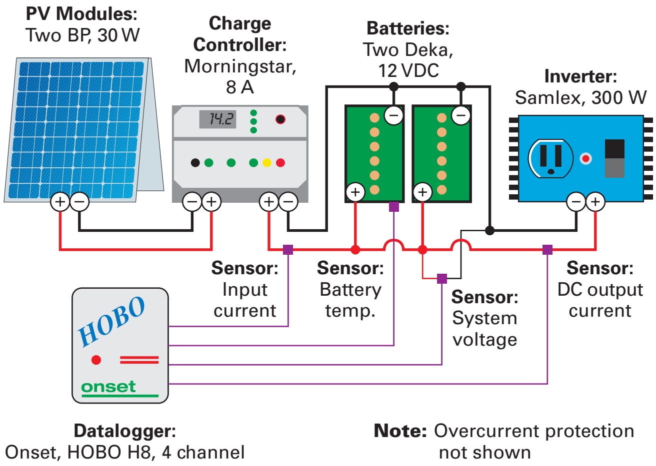
Sensor Development

The first sensor that we developed reduced a typical stand-alone RE system voltage of between 11 and 15.5 volts DC to the 0 to 2.5 volts DC range of the HOBO. Although there are several methods for reducing DC voltage, we used a voltage divider network that uses a couple of resistors wired in series. Despite its simplicity, this voltage divider circuit converts RE system voltages accurately, and can be easily adapted to system voltages up to 48 VDC nominal. (You can find more information on the design of a voltage divider circuit in any introductory electronics text, one of which is listed at the end of this article.)

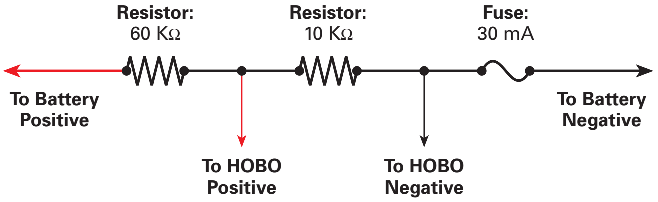
Developing the second sensor, which allowed the HOBO to measure DC amperage, was more difficult because we had to adapt a shunt resistor for use with the HOBO. Precision shunt resistors are often used for measuring direct current because they develop a small sensible voltage, or "voltage drop" that is proportional to the current through the resistor. The voltage drops associated with common shunt resistors, however, are too small to be accurately measured by the HOBO, so we needed a simple integrated circuit to amplify the minute voltage drops. This shunt and amplifier circuit can be adapted to a wide range of currents using a few resistors and some basic algebra. For design details, download the MAX472 component datasheet from www.maxim-ic.com.

The last step in developing our sensors was calibration, or determining the mathematical relationship between the measured value and the voltage that the HOBO recorded. We found this relationship by simultaneously measuring the quantity of interest (for example, a DC amperage) with both the HOBO sensor and an accurate digital multimeter.

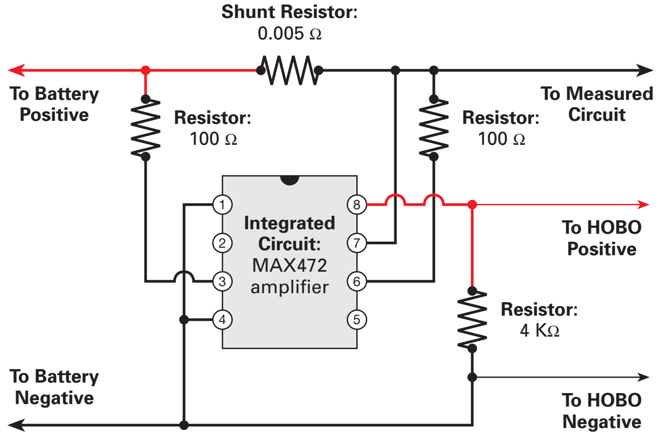
Datalogging System



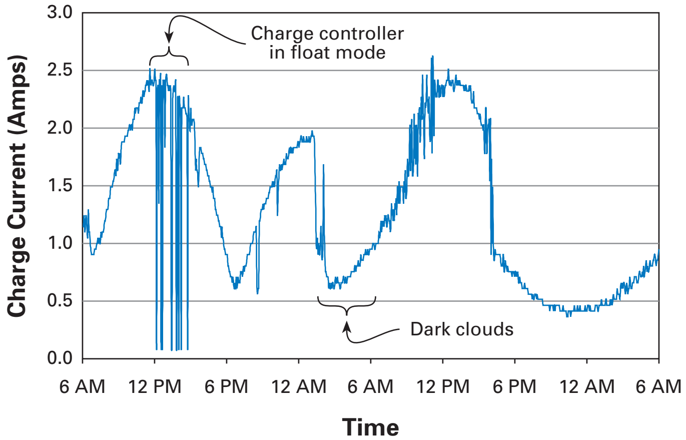
Voltage Divider



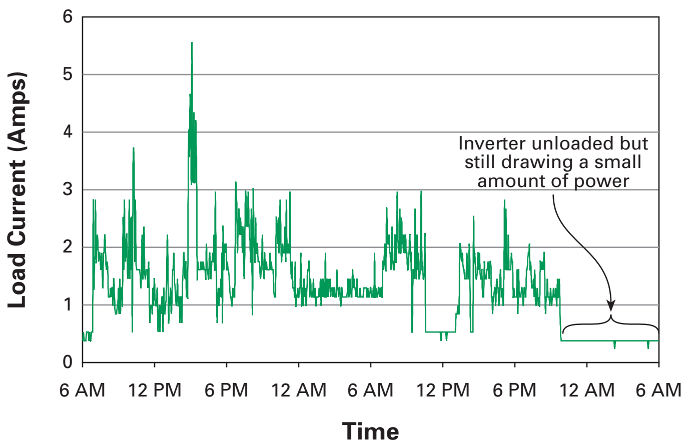
Current Sensor



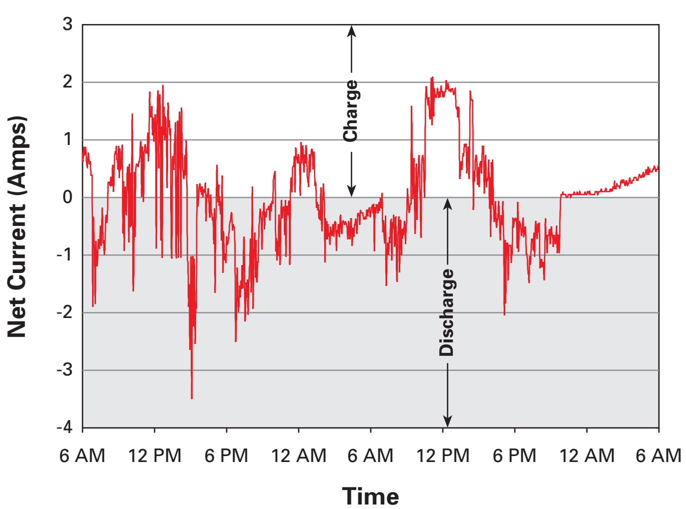
Charge Current



Load Current



Net Current



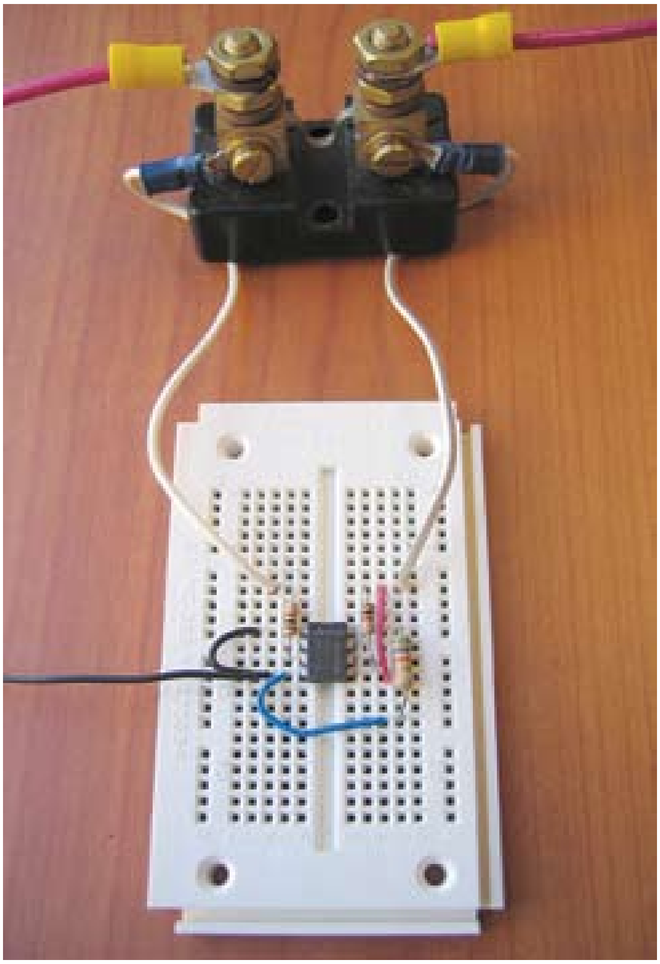
The mathematical relationship between the actual value, as measured by the multimeter, and the small DC voltage, measured by the sensor and HOBO logger, was our scaling factor. For example, if the HOBO measurement was 1.00 V and the actual multimeter measurement was 5.0 A, the scaling factor is 0.20 V per A.

Installing the Datalogger

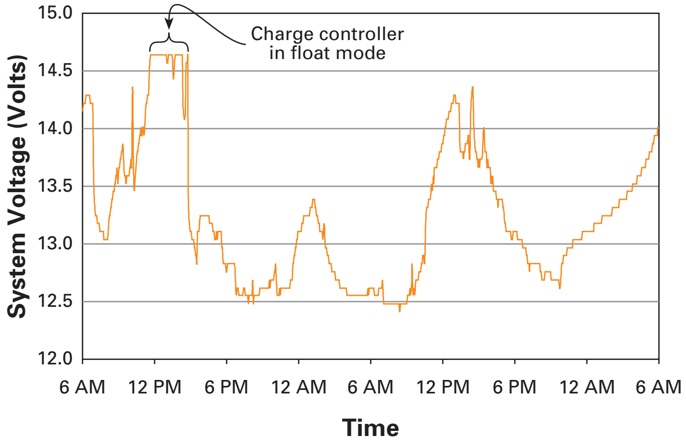
Having developed the necessary sensors, we connected the datalogging system to our portable solar-electric system and continuously measured system voltage, input current, output current, and battery enclosure temperature for two weeks. The system included two BP Solar 30 W PV panels, a Morningstar charge controller, two Deka 30 AH gel-cell batteries and a Samlex 300 W inverter. The schematic on the previous page shows the locations of the HOBO sensors relative to the system components.

The tests took place in West Antarctica during the Southern Hemisphere summer, so the system was operating in twenty-four hours of daylight, with temperatures ranging from -10°F to 20°F (-23°C to -7°C). The HOBO took measurements every three minutes on all four channels (input current, output current, voltage, and temperature), and we periodically verified the accuracy of the HOBO's measurements with a multimeter.

The custom current-sense circuit wired to a shunt, which is inserted into the circuit.



System Voltage



Analyzing the Data

After downloading two weeks of data from the HOBO, we used a spreadsheet to reduce and graph it. Graphs of solar input current, load current, and voltage showed us that our solar-electric array and battery bank were adequately sized for the test loads, and that the charge/load controller and inverter were functioning properly at a wide range of temperatures.

Because our system used a small PV array (60 W) for battery charging, the graph of DC input to the inverter also showed us that our inverter was consuming between 10 and 40 percent of the available solar energy, even when it was producing no AC electricity. This result suggested that we needed to devise an easy way to switch off the inverter when it was not in use, to reduce its idle draw on the small RE system.

The numerical data from the logger was very useful because it allowed us to calculate that our solar-electric array gathered 450 watt-hours (WH) of energy per day in full sun and 250 WH in overcast conditions. Based on this, we gave the users of our systems guidelines for how many hours per day they could run laptop computers, radios, satellite phones, and battery chargers.

Data Collection Costs

Item	Cost (US$)
HOBO H8 datalogger	$85
2 Shunt resistors	39
3 DC voltage input cables	32
Temperature sensor	27
HOBO BoxCar software	14
2 MAX472 amplifiers	10
Resistors, circuit boards, wires, solder	10
Total	$217

Future Applications

The results of our two-week test showed that, under typical Antarctic conditions, our solar-electric system operated properly, and our datalogging system accurately recorded voltages, currents, and temperatures. These results will help expeditions using such systems to plan their energy use.

After completing this project, we are convinced that the design and construction of an RE datalogging system is well within the financial and technical reach of many RE users. These datalogging systems can be adapted to measure many more RE system parameters than we have mentioned here, including solar irradiance, wind generator input, wind speed, and inverter efficiency. As a simple, adaptable, and inexpensive device, a datalogging system will be useful to any RE user who wants to improve an existing system, troubleshoot a faulty system, or simply enhance understanding of a system's dynamic operation.

Access

John Lyons, 65 Valley Rd., Allendale, NJ 07401 • 206-914-7865 • semeitau@yahoo.com

Joe Yarkin, 7330 SW 248th, Vashon, WA 98070 • 206-463-0007 • solarjoe@gmail.com

United States Antarctic Program, Office of Polar Programs, Rm. 755, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230 • 703-292-8030 • Fax: 703-292-9081 • dfriscic@nsf.gov • www.nsf.gov/od/opp/antarct/usap.jsp

Equipment Manufacturers:

Deltec • 562-926-2304 • www.deltecco.com • Precision shunt resistors

Digi-Key • 800-DIGIKEY or 218-681-6674 • www.digikey.com • Electronic components

Maxim Integrated Products Inc. • 408-737-7194 • www.maxim-ic.com • Current-sense amplifiers

Onset Computer Corp. • 800-564-4377 or 508-759-9500 • www.onsetcomp.com • HOBO dataloggers

Other Resources:

"Measuring Energy Usage for Inverter & Battery Bank Sizing," Mark Patton in *HP76* • A good introduction to the HOBO datalogger

Practical Electronics for Inventors, by Paul Scherz, 2006, Paperback, 704 pages, ISBN 0071452818, US$39.95 from McGraw Hill • 800-262-4729 or 609-426-5793 • www.books.mcgraw-hill.com

Adventures in Solar Hot Water Efficiency

The author's daughter Emily shows off the Heliodyne heat exchanger.

Jeffrey Beeman

When I was a kid, let's say a few decades before the twenty-first century, my friends and I were always messing around with stuff. Chemistry sets, model rockets, lawn mower engines, gunpowder…and none of these things were ever quite used as they were intended. Improvisation and wild entertainment were the goal of the day. I'd never let my kids do the stuff we did back then, and I'm happy that we made it into adulthood with all our fingers and toes.

Now that I'm in the "zenith of life," my motivations and sensibilities have changed quite a bit, but there seems to be a nugget of that same kid spirit that just powers on. I guess it's this passion to "tweak the status quo" that got me messing about with my hot water system.

In June 2003, my family installed a state-of-the-art, pressurized, glycol-loop solar hot water system on our house. The system diagram shows the setup. At the time, two 4- by 10-foot (1.2 x 3 m) collectors, a 119-gallon (450 l) preheat tank, a solar-powered glycol pump, and a thermosyphon heat exchanger all just sounded too cool to resist. This baby ran all by itself, without any complicated controls or 120 VAC electrical connection. All I had to do was install the system, live my normal life, and take as many hot baths as I could stand while the system took complete care of itself.

Unfortunately, this utopia came to a halt on day two of operation, when the pump up on the roof started to make a funny kind of squeal, and we started to see steam coming from the relief valves up on the panels. This was somewhat distressing to say the least, and I started to think about all the great steam-engine catastrophes I had ever read about.

Not only that, but my wife Carlene was giving me "the eye," which meant, "You spent all this money and it doesn't work?" I called my dealer–installer, who quickly came out, recharged the glycol loop, bled the system of all air, and got us up and running again—for about two weeks, anyway.

Eventually, the system halted again. My diagnostic bet was on the poor positioning of the pump in our system, at the very highest point of the entire glycol loop. If any air bubble whatsoever blipped its way through the system, it would eventually travel to this high point and cause the pump to lose its prime.

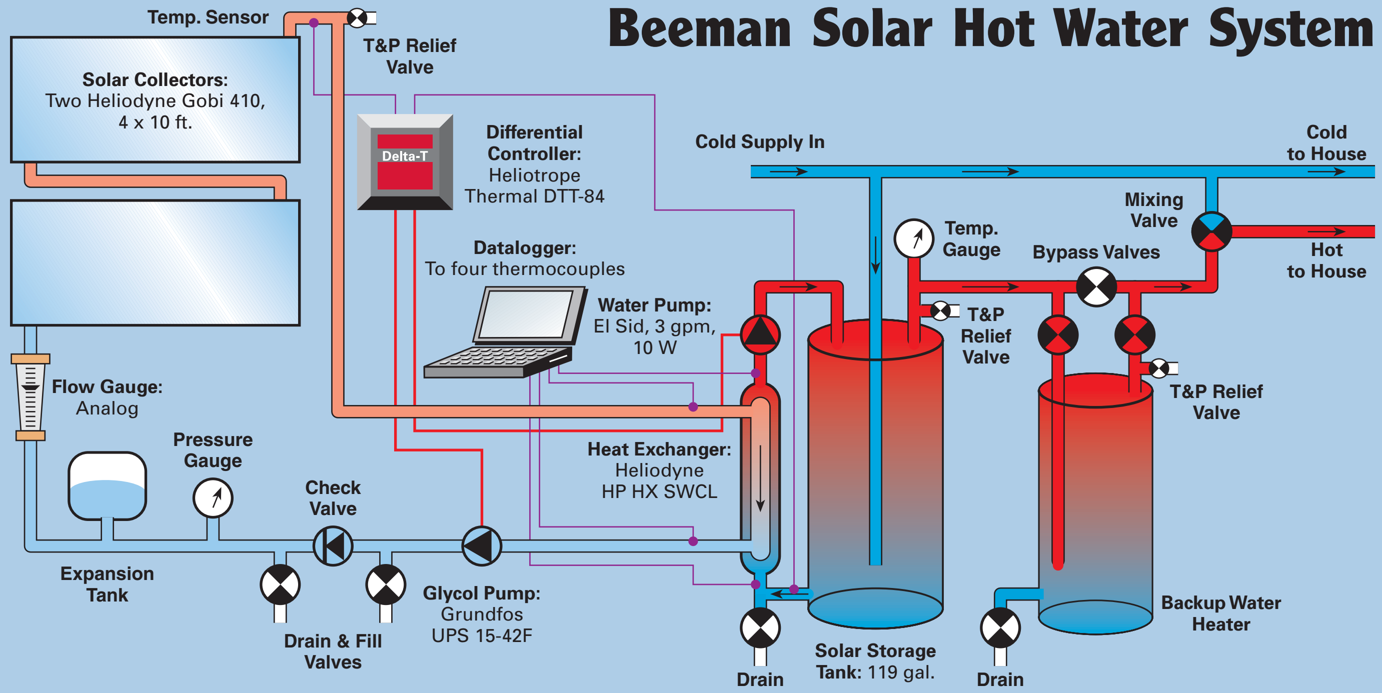
After several calls to the manufacturer of the system and our installer, I guilt-wrangled a new Grundfos 120 V pump and a conventional differential thermostat control box. The Grundfos was positioned on the return line of the glycol loop (at the low point in our system, down in our garage) and my hot baths and self-satisfaction returned. For a few more weeks, anyway, until that little "tweaking voice" started to whisper in my ear again.

Two 4- by 10-foot thermal collectors (behind PV array) face due south on a west-facing roof.

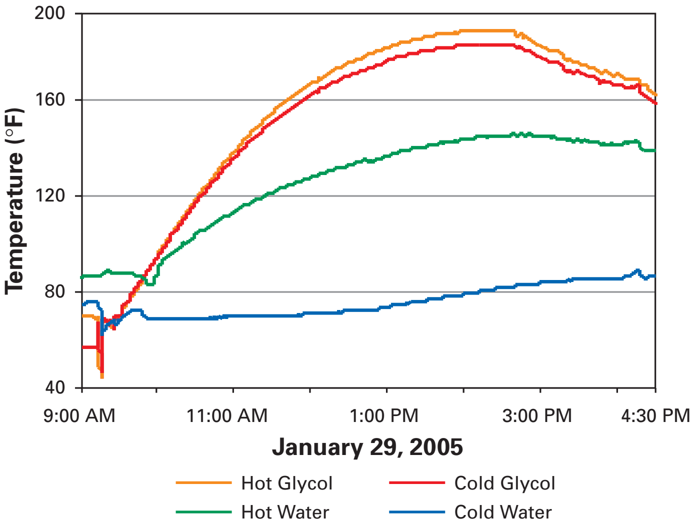
Instinct Takes Over

"Now what?!" Carlene exclaimed with a glint of impatience in her eyes. I was out in the garage climbing all over the solar tank with a gizmo in my hand, poking and probing here and there. The gizmo was a thermocouple meter, which is a very sensitive electronic thermometer that has a probe in the shape of a fine wire. I was checking the temperatures of the hot glycol solution coming from the roof, the cold glycol return, the cold water entering the heat exchanger, and the hot water being produced. "I don't know…" I replied, "Something still doesn't seem right."

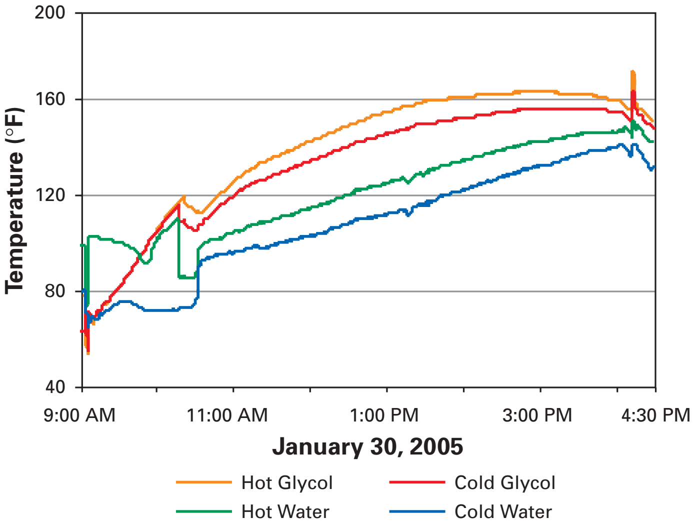
Beeman Solar Hot Water System



Thermosyphon System Performance



Pump System Performance



On this particular morning, I was measuring 128°F (53°C) hot glycol entering the heat exchanger and 116°F (47°C) glycol coming back out, but I was only making 102°F (39°C) hot water from the 93°F (34°C) water at the bottom of my tank. I poked around like this for several days and took a few pages of notes. It seemed kind of lousy to me that I was only making 102°F water when I had 128°F glycol coming from the roof.

I called the manufacturer and told them all about my measurements and my concern that our system just wasn't very efficient. I was told that "Yes, Mr. Beeman, you are very clever, but you simply don't understand how these systems work. Are you getting 160°F (71°C) water at the top of your tank on a warm, sunny day?" "Yes," I admitted, "but the heat exchanger doesn't seem to be very efficient." "Ah, well, Mr. Beeman, you simply don't understand how these exchangers work either." Maybe so, I thought, but I did understand how to search the Internet.

A little poking around revealed a paper presented at the 1999 American Solar Energy Society Conference. Researchers at the University of Minnesota (U of M) described several different styles of heat exchanger typically used on thermosyphon solar hot water systems, and predicted how these heat exchangers would perform under various conditions.

Although the paper was based on a mathematical model, the authors predicted rather crummy thermosyphon performance for the exact style of heat exchanger that I had. The paper also showed that while there are more efficient heat exchangers on the market, the most effective way to boost these systems is to add a low-flow pump to the water circuit. What? This didn't make sense at all! Several solar energy gurus report that thermosyphon systems are the best thing since sliced bread—there are no moving parts, they deliver the hottest water to the top of the solar tank, etc. It all made sense to me. Not so, said the researchers from U of M.

Next thing I know, I'm sitting on a stool in my garage, staring at my hot water tank like Rodin's *The Thinker*. Sitting over in a corner, I notice the leftover parts from the original system configuration, including a little 10-watt El Sid water pump. Hmm. Isolate, drain, saw, solder, hook up—the El Sid practically leaped into my water circuit by itself!

A computer logs data from the solar hot water system's final configuration using four thermocouple sensors.

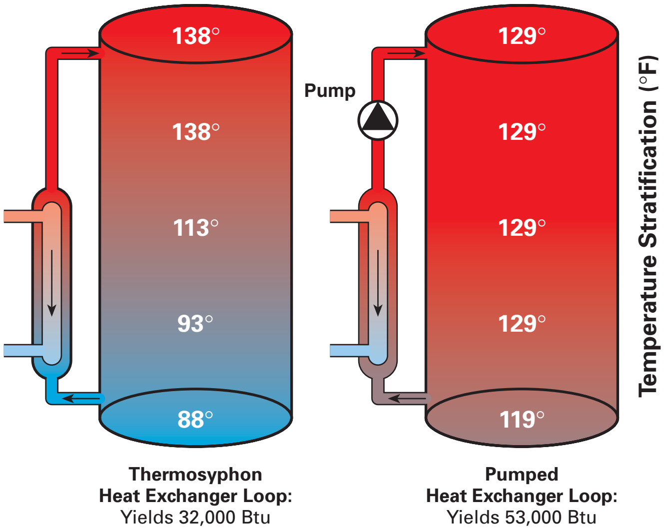
Around this same time, I also purchased a four-channel thermocouple monitor from National Instruments that connects to the USB port of a computer. It reads four thermocouples simultaneously and dumps the data to my computer. It's a very handy gadget when you have hot glycol, cold glycol, hot water, and cold water to measure. Now I can see exactly how the system works with the water pump on or off.

The graphs show that the ultimate temperature of the solar-produced hot water is indeed higher for the thermosyphon system, given similar water starting temperatures and similar solar energy hitting the panels. They also show that the cold-water side is getting warm on the pumped system, indicating that the tank heats all the way to the bottom in this case. But how are we supposed to know which is more efficient? Enter thermocouple No. 5. (Yes, I am in love with thermocouples.)

Thermocouple Madness

This time I purchased a thermocouple unit that's 6.5 feet (2 m) long. I can lower it into the solar tank and read the water temperature at various heights in the tank before and after a day's run. (If you don't remove all of the pressure in the tank before trying this, you can blow steaming water all over your garage and totally crack up your kids.)

Temperature Gain by Circulation Type



I know that my tank is 119 gallons (450 l), and I know that the shape of the storage area is roughly an upright cylinder. With a little math, I can chop up the water column into 1-foot (0.3 m) "slices," figure out the average temperature per slice, and calculate the Btu that this represents. If I take the temperature-versus-depth readings in the morning and again in the evening, I've got the daily Btu harvest and can now compare the "pump on" and "pump off" configurations, right?

Well…this is only partly true. Heat exchanger-based systems rely on temperature differential to transfer heat. The greater the difference in the temperatures between water and glycol, the more effectively the heat transfers. If I want to compare the two configurations fairly, I would have to start with exactly the same temperature stratification and

The author checks the stratification of the solar tank with a 6.5-foot-long thermocouple. Daughters (and sons) make great dataloggers.

A simple, handheld temperature meter with a fine-wire, Type K thermocouple is a great tool for quick diagnostics.

Tech Specs

System Overview

Type: Pressurized glycol with two-loop heat exchanger; glycol and water loops both pumped

Location: El Sobrante, California

Solar resource: 5 KWH per square meter per day

Production: 2,700,000 Btu per month average (27 therms)

Percentage of hot water produced annually: Approximately 70 percent

Equipment

Collectors: Two Heliodyne Gobi 410, 4- x 10-foot panels

Collector installation: Roof, due south orientation, 45-degree tilt angle

Heat transfer fluid: Heliodyne Dyn-O-flo HD

Circulation pump: Glycol pump, Grundfos UPS 15-42F; Water pump, El Sid, 3 gpm, 10 W

Pump controller: Heliotrope Thermal, model DTT-84

Storage tank: American Water Heater Company, model SE62-119R-045S, 119-gallon capacity

Heat exchanger: Heliodyne HP HX SWCL

System Performance Metering

Thermometer: Omega HH11 thermal meter with Type K thermocouple, later switched to National Instruments four-thermocouple/USB interface, model NI USB-9161

Flow meter: Letro 5 gpm sight glass meter (glycol side)

Pressure: BCS pressure gauge, 160 psi max

starting Btu (not to mention having exactly the same amount of solar energy shining on the collectors every time). Given these conditions, and the forecast of a clear, sunny week in January, I decided to put my tinkering to the test.

During two consecutive sunny days, I isolated our solar tank from the house, and partially drained and refilled the tank. I started with an 83°F (28°C) average water temperature in the tank in "thermosyphon mode" the first day, and 89°F (32°C) average tank temperature in the "pumped mode" the second day. I also monitored the system with the four-thermocouple setup to make sure that the solar profile was similar for the two days (no cloud cover throughout the day, for instance). The diagram and graphs on the previous pages show the final tank stratification and Btu harvest in each case. The pumped system is the clear winner.

Since making the measurements above, I have also mounted a snap switch on the hot glycol pipe. This little gadget, normally found on hot-air heating systems, closes an electrical contact when it senses a preset temperature. It opens again when the monitored temperature drops by 20°F (11°C) or so.

This switch, in series with the system "turn on" signal, controls the El Sid water pump so that it only starts when the hot glycol is above 120°F (49°C). If we don't use this, there is a slight chance (on a partly cloudy day, for instance) that the system will start the El Sid when the glycol isn't all that hot. This would only serve to mix up the tank, ruining the nighttime stratification.

The Bottom Line

These results confirmed my suspicions (and the predictions from the U of M) that thermosyphon systems stratify nicely, but they are likely to be much less efficient than double-pumped systems. In addition, we have seen that our present system typically delivers a full tank of 130°F (54°C) water during a sunny winter day, which is plenty hot enough to fully heat our water, preventing the backup element from running. In the summer, we reach 160°F (71°C) or more,

Beeman System Costs

SDHW System	Cost (US$)
Installation	$3,734
2 Gobi 410 collectors	1,900
American Water Heater Co. solar storage tank, 119 gal.	1,260
Heliodyne HP HX SWCL heat exchanger	450
Misc. copper pipe, vent valves, three-way valves, etc.	350
El Sid, 3 gpm, 10 W pump (for water)	205
Heliotrope DTT-84 differential controller	150
Antiscald valve	135
Grundfos UPS-15-42F pump (for glycol)	130
Heliodyne Dyn-O-flo HD propylene glycol, 4 gal.	116
Total System	$8,430

Data Collection	
National Instruments thermocouple monitor	395
Omega HH11 thermal meter	65
Omega 5SC-GG-K-30-36 thermocouple	58
Omega Type K thermocouple extension wire, 25 ft.	29
Total Data Collection	$547
Grand Total	$8,977

and since we now have a full 119 gallons of solar hot water during summer or winter, we can preheat over a greater number of subsequently cloudy days.

(Almost) No End to Tinkering

As time goes on, I find that I am continuing to mess with our system. The U of M article indicates that better heat exchangers are available, so we may try this upgrade next. I'm also working on software that can perform real-time efficiency monitoring so that I won't have to constantly dip thermocouples into the solar tank. After the "production end" is as efficient as possible, I want to play with hydronic heaters in my house. We currently produce quite a few more Btu than we typically use, and our ultimate goal is saving natural gas, money, and reducing our production of carbon dioxide (CO_2), not just producing hot water for the sake of hot water. Using some of the excess for home heating makes sense. For now, though, I'm quite happy with the cheap-but-effective improvements to date, and my wife, arms still crossed, seems to be finally showing a hint of a smile.

Access

Jeffrey Beeman, 5020 Santa Rita Rd., El Sobrante, CA 94803 • 510-243-6606 • Fax: 510-243-6606 • thehybridhome@yahoo.com

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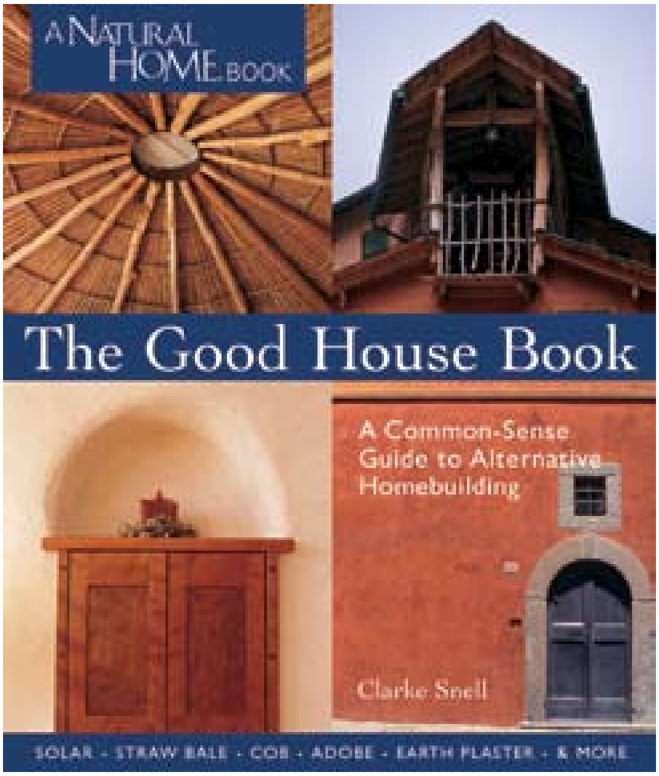
"Comparison of Natural Convection Heat Exchangers for Solar Water Heating Systems," by W. Liu & J.H. Davidson, proceedings of the 1999 American Solar Energy Society Conference, Portland, Maine, June 1999 • www.me.umn.edu/~weiliu/ms.html

"Solar Hot Water Simplified," by John Patterson in *HP107*

The Good House Book
A Common-Sense Guide to Alternative Homebuilding

Reviewed by Laura Bartels



It is common for natural builders and homeowners to label a house by naming the main material used, such as a "straw bale" house or a "cob" house. Accordingly, most new books in the natural building arena often focus on a single material. In *The Good House Book*, author Clarke Snell implements a useful and noteworthy strategy for discussing natural building and takes a comprehensive view of a house as "a building designed to sustain human life."

Instead of being organized topically by the many natural building materials covered, Snell chooses to "look at the problems buildings are solving and to lump similar solutions together." Chapter titles such as "Structure," "Temperature," "Separation," and "Connection" serve as examples of how the author considers the important roles our houses play in sustaining us—protecting us from the elements, while connecting us to the natural cycles that support life.

Snell has clearly done his homework on the variety of issues and discussions related to designing and building "alternative" houses. He provides clearly written overviews of foundations, walls, roofs, water, and energy and waste systems. Materials—from historic to modern, conventional to alternative—are compared and evaluated. Snell also provides interesting sidebars on such varied topics as the ancient technology of Roman concrete, Baubiologie, tensile fabric structures, and urban sustainability.

More than 300 photos, many taken in places such as Mali, Thailand, Tibet, Jordan, and Vietnam, help share a traditional perspective that Snell uses to compare both modern and alternative building approaches in each section of the book. With examples of native and modern design approaches, materials, and creative detailing, the photos also guide the reader on a journey from how houses have been built and how they are being built to how they could be built. Very clear illustrations throughout the book depict useful information, such as how various foundation styles function and how different systems can be combined to make a "hybrid" house.

In Chapter 7, "Six Approaches to a Good House," Snell shares interviews and abundant photos from different owner-built projects from the across the United States. Although he acknowledges that the projects don't necessarily represent the most natural approaches or sustainable choices, he suggests that what matters most is using examples like these to learn to ask the right questions. The book also describes a few concepts that are already outdated, such as using internal rebar pinning in straw bale walls. Keep this in mind as you plan and design your good home.

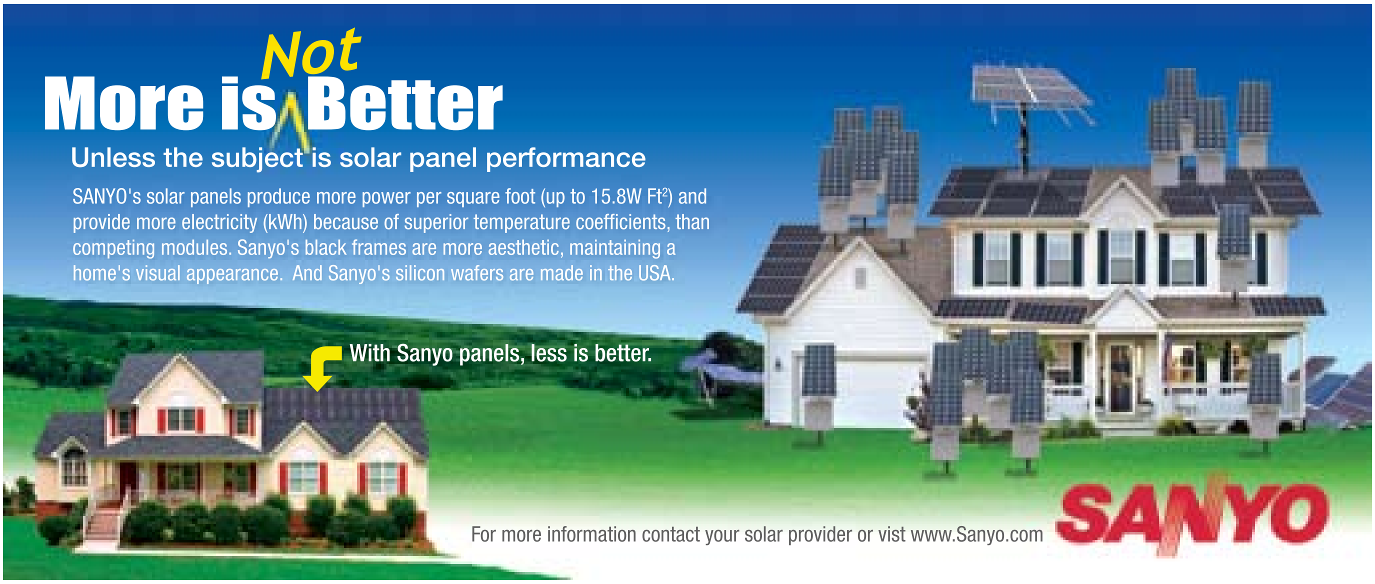
Snell says that for him, "alternative building [is about] how you are, how your land is, and how the two can come together." Having built his own passive solar house, and having worked at the Center for Maximum Potential Building Systems in Austin, Texas, building the Green Builder Demonstration Home, Snell speaks frankly from his own experiences throughout each chapter. At the end of the book, he says that "the paradox of building a house is that you have to remain grounded in reality while dreaming…It's the dance between these two poles that ultimately will lead to what will truly be your good house."

In your journey towards building a home, wandering through the pages of this book will help you navigate your own path. Snell's goal in writing this book was "to simply help you start thinking about things that will lead you toward a good house." And that he does.

Access

Laura Bartels, GreenWeaver Inc.—Sustainable Building, Consulting & Education, PO Box 912, Carbondale, CO 81623 • 970-379-6779 • Fax: 970-963-0905 • laura@greenweaverinc.com • www.greenweaverinc.com

The Good House Book: A Common-Sense Guide to Alternative Homebuilding, by Clarke Snell, 2004, Paperback, 240 pages, ISBN 1579902812, US$19.95 from Lark Books • 800-284-3388 • www.larkbooks.com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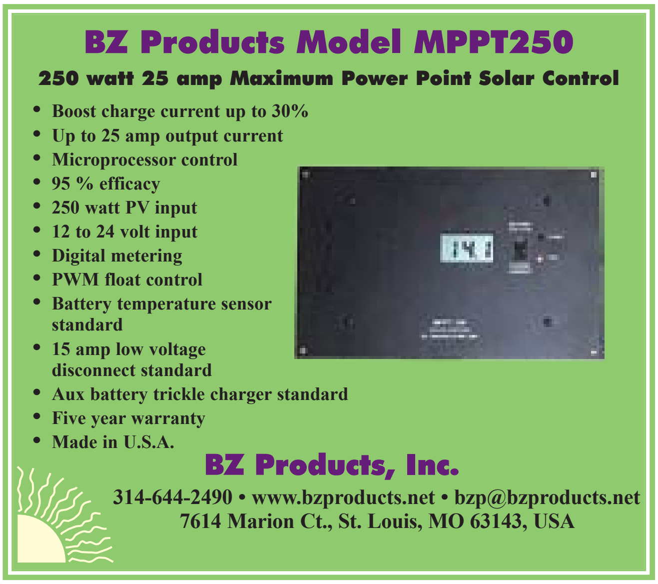
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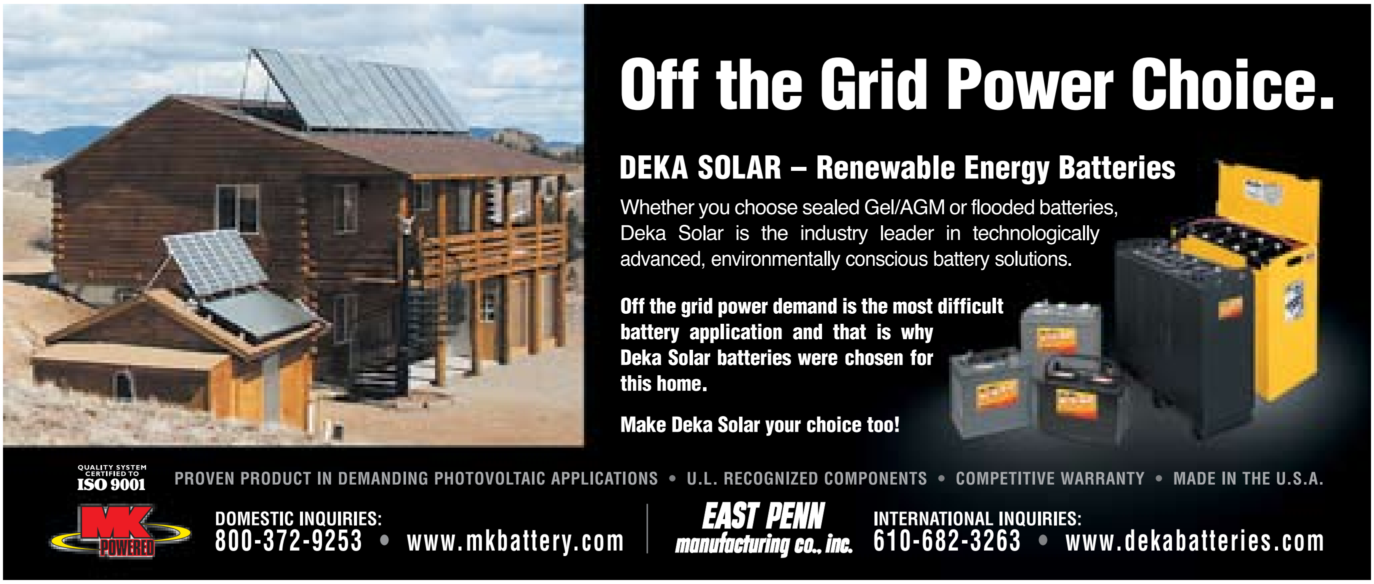
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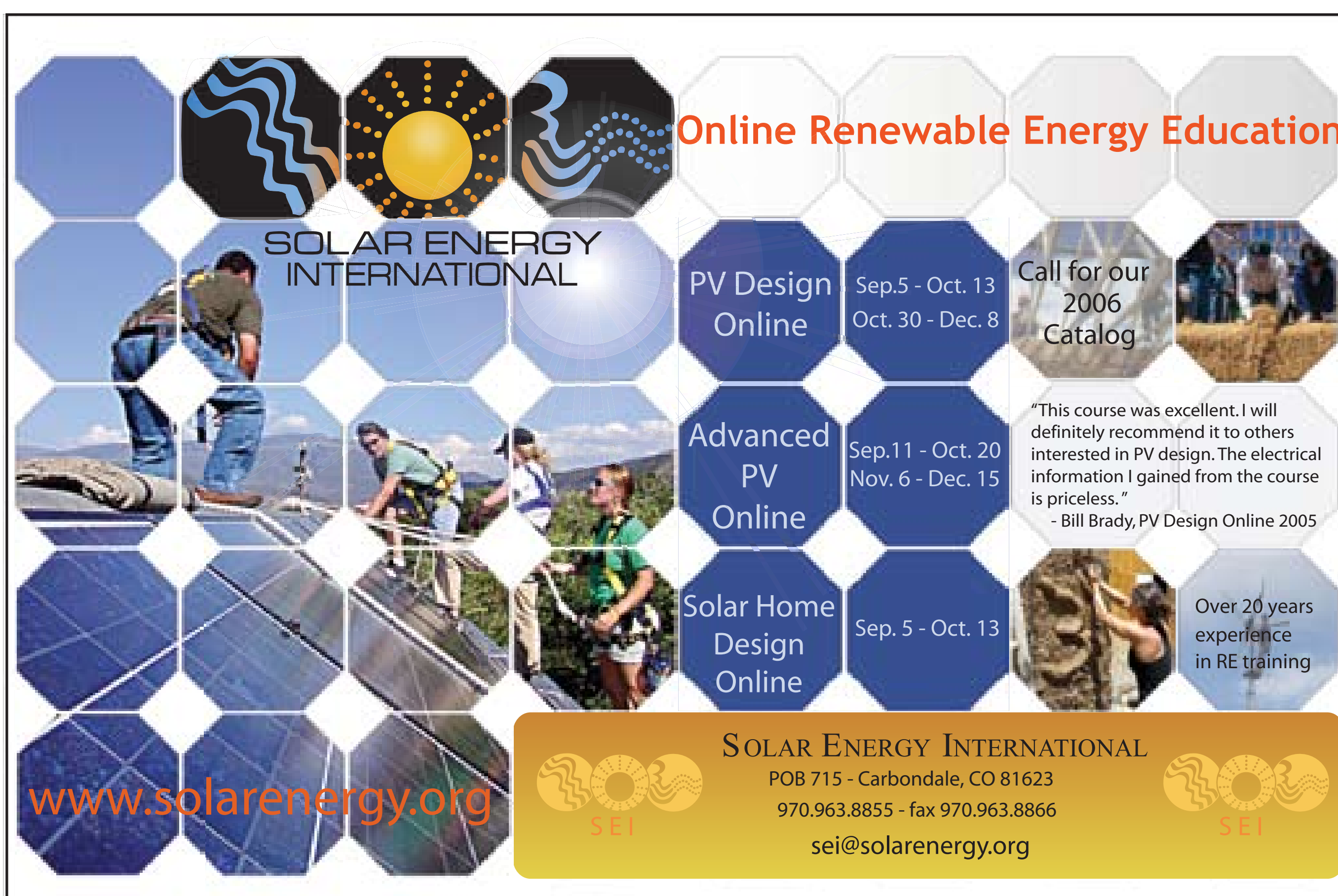
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The Myth of a Hydrogen Future

Ulf Bossel

Global warming and dwindling oil and gas reserves remind us that we are approaching the end of the fossil energy road. But how can we prepare for the unavoidable end of the fossil fuel era and meet our energy needs sustainably, without using more energy than nature can provide indefinitely, and without leaving waste that nature cannot assimilate?

In a sustainable future, solar energy, wind, running water, geothermal heat, and biomass will become the only viable energy sources. Energy will become a precious commodity that will have to be distributed to consumers with the highest efficiency, and used intelligently to provide maximum comfort and services from every energy unit harvested and delivered. The efficient use of energy and its conservation will become the cornerstones of this sustainable energy future.

However, there seems to be no clear picture of the sustainable economic *mix* of energy sources, energy distribution, and energy demand. The future will most likely not be based on a one-to-one replacement of fossil fuels by renewables, but will rely on a more complex substitution of processes involving physical and chemical energy carriers.

It would take twenty-two trucks carrying hydrogen to transport the same energy contained in one gasoline tanker truck.

Renewable energy will be harvested mainly in the form of electricity—direct current (DC) from photovoltaic arrays, and alternating current (AC) from rotating generators powered by wind and water, or steam turbines that convert geologic or solar heat into electricity. Solar heat will also be used for water and space heating. Biomass from plants and organic refuse will become feedstock for liquid biofuels. So how does hydrogen fit into this energy equation?

Hydrogen—Just Hype?

Just as it was in the 1920s, the '50s, and again in the '70s, a hydrogen energy future is offered as a solution. But today's hydrogen promoters have joined journalists and lobby groups to convince politicians to fund extensive programs—at the expense of ignoring other readily available and proven renewable energy (RE) technologies.

Hydrogen is not a new energy *source*, but rather an energy *carrier*—like water in a hydronic heating system or electrons in a copper wire. And this energy has to come from somewhere. In a sustainable energy future, hydrogen will be produced mainly by the electrolysis of water. But to carry the energy equivalent of 1 gallon (3.8 l) of gasoline, 2.4 gallons (9 l) of water are needed to yield 2.2 pounds (1 kg) of hydrogen. To satisfy all present transportation energy needs of the city of Los Angeles with hydrogen would double the water consumption rate of the city and require the continuous output of the equivalent of about 100 nuclear power plants.

Energy Losses

All energy conversion processes are associated with energy losses. The highest losses occur when chemical energy (coal, oil, natural gas, or hydrogen) is converted to physical energy (electricity, motion, pressure) in power plants or internal combustion engines. Those efficiencies can be far below 50 percent.

When physical energy is stored in a chemical energy carrier, the losses are equally significant. The electrolysis of water is a good example. The hydrogen produced carries much less energy than the energy required to separate it from water.

Promoters of a hydrogen economy argue that hydrogen also can be produced from natural gas or biomass. In both cases, chemical energy is converted into hydrogen energy with the help of heat obtained by burning fuels. But again, when the original energy content of the fuels is considered, hydrogen carries much less energy, compared to what was required for its production. The high losses of hydrogen production might be tolerable if the distribution of the energy carrier was much more efficient than energy distribution by electricity. However, this isn't the case.

Hydrogen & Distribution

Hydrogen is not a good energy carrier, mainly as a result of its unique physical properties of being the lightest of all elements and having an extremely low boiling point. Because of its low density, it must be compressed or liquefied for transport. Both of these processes require energy. Compression requires about 10 percent of hydrogen's energy content; liquefaction consumes about 30 to 40 percent. Twenty-two tube trailers loaded with hydrogen at 3,500 psi would be needed to match the energy contained in a *single* gasoline tanker truck.

The graph below shows the most significant results of this energy analysis. About half of the original electrical energy is lost between the power plant and the hydrogen outlet at filling stations or homes. If hydrogen is reconverted to electricity with 50 percent efficient fuel cells, about three-quarters of the original electrical energy is lost. The point is that our energy problem certainly will not be solved by *wasting* energy.

Because hydrogen is not an energy source, it's only as clean as the energy source from which it is derived.

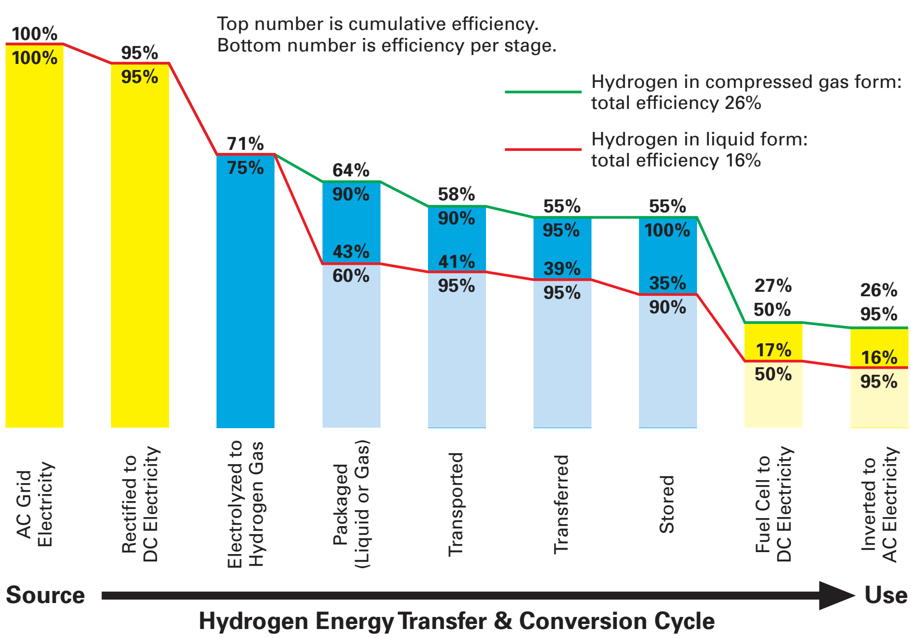
Because of this, promoters of "green" hydrogen should be aware that nuclear energy may be the only practical energy source for the inflated energy demand a hydrogen economy requires.

Sustainable Structures & Costs

Wind can already be harvested profitably along the coasts and in many other areas throughout the country. It is estimated that only 0.16 percent of the U.S. land mass would be required to generate 300 gigawatts of continuous wind energy—enough to meet the entire electricity demand of the United States. These wind farms could be installed on farm and grazing lands, far away from population centers. Coupled with energy efficiency measures and photovoltaic arrays on most south-facing roofs, this energy mix could provide enough energy to meet our demands.

Before a sustainable energy economy is established, the costs for natural gas and heating oil will have reached levels that make energy conservation by using thermal insulation, better glazing, and appropriate architecture economically attractive. By implementing these measures, the heating and cooling demands of residential buildings could easily be halved. Electric heat pumps will replace fossil-fuel-based central heating systems, and heating oil will be rerouted to fuel vehicles. Building energy conservation may act to extend the fossil era in the transportation sector, making the early establishment of a hydrogen infrastructure less likely.

Efficiencies of Hydrogen Energy Production & Transmission



The transition from today's energy economy to a sustainable energy economy will also affect the energy cost structure. Because of the inherent losses directly associated with hydrogen production and distribution, hydrogen energy will cost at least twice as much as electrical energy, and hydrogen-derived electricity will be four times as costly as electric power from a wall socket. This will result in a complete reversal of the entire energy market. Energy prices will no longer be set by oil or gas, but by the cost of renewable electricity.

Effects on Transportation

As RE-generated electricity from the grid will cost only half as much as the hydrogen energy offered by filling stations, electric cars—not hydrogen fuel cell vehicles—may become the preferred option for commuters. The power-plant-to-wheel efficiency of electric cars approaches 60 to 70 percent, compared to fuel cell vehicles, which have "wind-to-wheel" efficiencies between 17 and 23 percent when energized with liquid or gaseous hydrogen derived from renewable sources.

In a sustainable energy future, millions of electric vehicles may be in daily use for local driving. Unlike the hydrogen infrastructure, which has yet to be developed, the energy infrastructure to support "fueling" these vehicles already exists, or could be easily implemented.

With all-electric commuter cars and automatic battery chargers in every garage, bigger vehicles will most likely be hybrid electric, operating on batteries for short trips and burning liquid hydrocarbon fuels like methanol or biodiesel on longer hauls. Many hydrocarbon fuels are as universal as elemental hydrogen. Biomethane carries 3.5 times more energy per volume than hydrogen gas at the same pressure. It is very unlikely that synthetic hydrogen will be derived from biomethane, because it is much more difficult to distribute and store onboard in sufficient quantities and over longer periods. Also, most liquid hydrocarbons contain more hydrogen per volume than liquid hydrogen. This suggests that hydrogen should be packaged in synthetic hydrocarbon *carriers* rather than be distributed in its elemental form.

Future Forward

An analysis of the energetics of a sustainable energy economy indicate that hydrogen's role will be limited to applications like space flight or submarines, or for storing electric energy from intermittent sources. Hydrogen may also provide energy for portable systems, or serve as clean energy applications for mining or in places where equally clean renewable energy solutions, like wind or PV, cannot be implemented. But because of the high losses associated with hydrogen's production, packaging, and distribution, hydrogen will likely remain an expensive luxury fuel.

But what about the future role of fuel cells? We need fuel cells now for the efficient and clean conversion of natural gas and liquid hydrocarbons like oil and gasoline. They have the potential to be more efficient and less polluting than internal combustion engines and gas turbines. Fuel cells with internal reforming (the ability to chemically convert hydrocarbons into hydrogen and carbon monoxide) offer inherent advantages over hydrogen-only systems. Even in a distant future, fuel-flexible cells will be used to convert synthetic hydrocarbons into electricity.

However, fuel cells shouldn't serve as a justification for a premature and hasty change of our energy system. A hydrogen economy should only be established if it makes economic and environmental sense, not because there are fuel cells waiting for hydrogen. Introducing a new energy carrier will not solve our energy problem, and it makes no sense to develop and introduce technologies to prepare for a "transition" to an energy future that cannot meet our future needs.

Because of its low energy efficiency, a hydrogen economy cannot be sustainable. However, a sustainable energy future can certainly be realized with energy conservation, efficient energy distribution, and the intelligent use of energy from renewable sources. With respect to overall efficiency and environmental friendliness, and by the fundamental laws of physics, hydrogen can never compete with its own source of energy.

Access

Ulf Bossel, European Fuel Cell Forum, Morgenacherstrasse 2F, CH-5452, Oberrohrdorf, Switzerland • forum@efcf.com • www.efcf.com • Ulf Bossel holds a degree in Mechanical Engineering from the Swiss Federal Institute of Technology (ETH) at Zurich and a doctorate from the University of California at Berkeley.

Bossel, Ulf, Baldur Eliasson, and Gordon Taylor, "The Future of the Hydrogen Economy: Bright or Bleak?" • www.efcf.com/reports/E08.pdf or visit *Home Power*'s Promised Files page at www.homepower.com/promisedfiles

Build a Low-Cost SOLAR COOKER

Jim Taulman

Renewable energy enthusiasts like me are always looking for new ways to spread the word about sustainable, fossil-fuel-free living—and solar cooking is one of the easiest ways to demonstrate the amazing, useful energy of the sun. Students enjoy hands-on projects they can accomplish together, and almost everyone can appreciate the financial merits of using free, abundant energy. And what better way to reach folks than through their stomachs—with something delicious baked in a homemade solar cooker?

I admired Jay Campbell's washtub solar cooker design, described in "A Kitchen in the Sun" (*HP37*), and constructed one to use in the renewable energy class I teach at Oglala Lakota College (OLC) on the Pine Ridge Reservation in South Dakota. One of my students, Valerie Janis, took on the role of student teacher. She created a PowerPoint presentation on solar cooking, and together, we built a prototype cooker. While she got some hands-on experience with its construction, I worked on improving the patterns and assembly directions.

Class participants used our step-by-step instructions and patterns to mark cutout lines on the sheets of hardboard (such as pegboard) and plywood. For safety's sake and to speed up the assembly process, I used my table saw and circular saw to cut out the pieces. Participants then assembled the oven and reflectors as a group with Valerie's help, according to Jay Campbell's original directions and some modifications I had added. At the end of class, we held a drawing and awarded the finished washtub cooker to one of the class members to take back to use at their school.

Tools...

- Circular saw
- Table saw or jigsaw (handy, but not required)
- Measuring tape
- Chalk line
- Framing square
- Flat-blade and Phillips screwdrivers
- Drill and 1/8-inch drill bit
- Hammer
- Utility stapler or hammer stapler
- Wire cutters, tin snips, or utility knife
- Clamps
- Safety glasses
- Hearing protection

Step One: *Mark & Cut Out Pieces*

A. Reflectors: Measure and snap chalk lines (as detailed in illustration) on a 4- by 4-foot piece of 1/8-inch hardboard, and cut out shapes using a circular saw or table saw.

B. Box, Box Top, Mounting Strip & Frames: Measure and snap chalk lines (as detailed in illustration) on a 4-by 4-foot piece of 3/8-inch plywood, and cut out shapes using a circular saw or table saw.

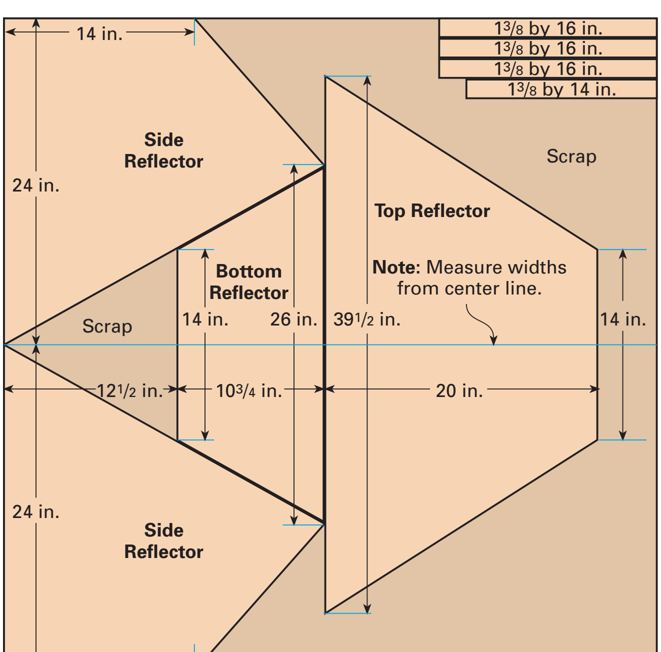
C. Cut out 14- by 14-inch squares from the 18-inch squares using a circular saw or a jigsaw. You'll end up with a 14-inch square piece for the bottom of the oven box, a 14-inch square piece of scrap, and two "frames."

D. Cut a 1 1/2-inch strip from one side of the 14-inch square scrap. You'll attach the rear reflector to the glass frame by using this mounting strip, which also allows the side reflectors to fold in on the back reflector, and lie flat for transporting and storing the oven.

E. Sand all edges of cut pieces smooth to prevent splintering.

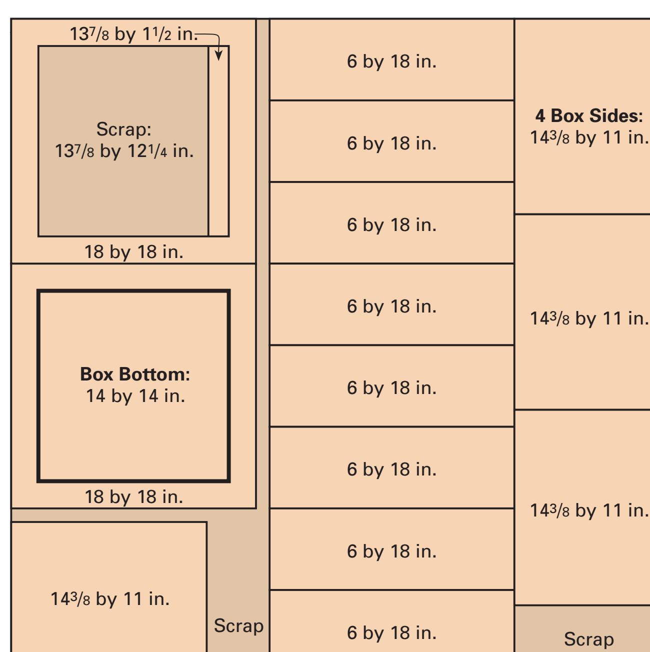
Laying out the pattern for a side reflector. After the measurements are transferred to the hardboard or plywood, use a chalk line to "snap" straight lines for the pattern pieces.

Reflectors



Hardboard: 4 by 4 ft., 1/8 in. thick

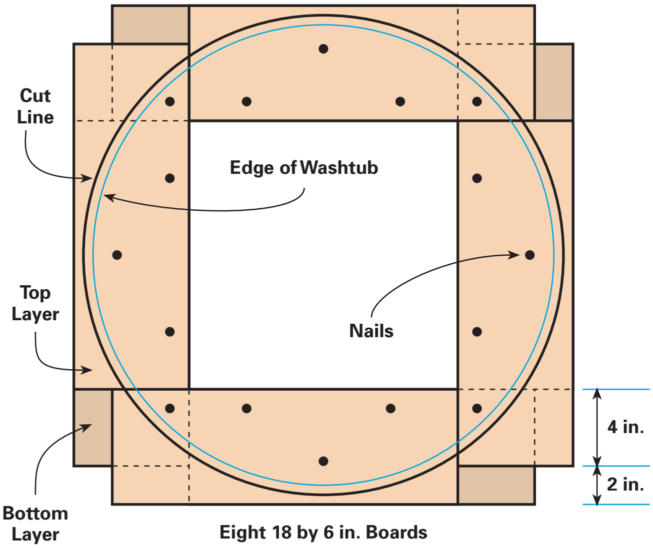
Oven Box & Lid

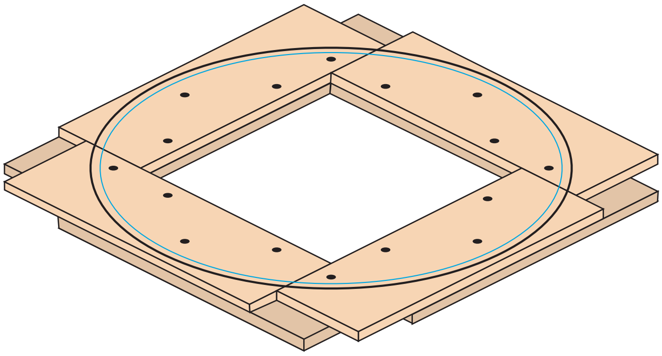


Plywood: 4 by 4 ft., 3/8 in. thick

Fastening the oven box sides to the box bottom.

Oven Box Lid





Two Layers Glued & Nailed Together

Step Two: *Assemble Oven Box & Box Top*

A. Glue and nail the 14 3/8-inch sides to the 14- by 14-inch bottom to make the oven box, overlapping the corners as shown in the photo at left. Use the 1-inch nails.

B. Glue aluminum foil to the inside of the box, using a 1:1 glue and water mixture; spread with a paintbrush.

C. On a flat surface, turn the assembled box upside-down and stack two levels of the 18- by 6-inch box top pieces snugly around the box, overlapping the second level as illustrated. The pieces won't extend out to make a perfect square; there will be a 2-inch "gap" at each end. Once the pieces are in position, glue and clamp them in place.

D. Remove oven box and center the upside-down washtub on the box top. With a pencil, trace a line around the outer rim of the washtub.

E. Remove the washtub. Nail box top pieces together using the 3/4-inch nails, placing them at least 1 inch inside the circular tracing line. (Do this to prevent cutting through any nails when you're sawing out the circular top.)

F. Use a jigsaw or circular saw to cut a circle about one-half inch *outside* of the penciled mark to ensure the top will overlap the washtub's rim. Sand the edges smooth.

G. Attach the weather-stripping on the marked circular line to form a seal when the box top is seated on the washtub.

H. Run a bead of wood glue along the inside rim of the box top and place it over the oven box so that the top of the oven box is flush with the box top. Drive 1-inch nails through the inside of the box to attach the box top.

I. On the face of the box top, attach another piece of weather-stripping about half an inch from the opening. Make sure that the stripping forms a continuous, single layer so that the glass frame will lie flat on it.

Cutting out the circular top.
In the background—the finished oven box.

Step Three: *Assemble the Glass Frame*

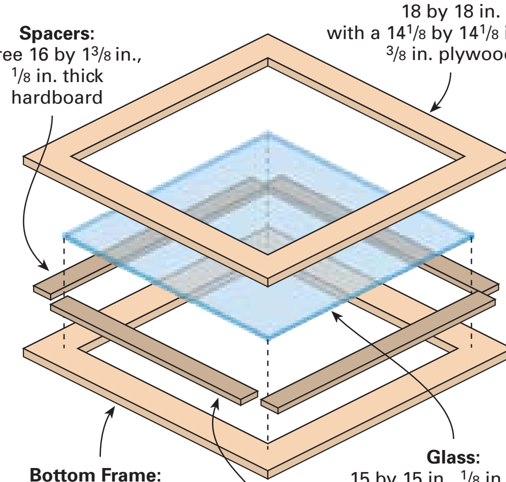
A. On the 18- by 2-inch frame, position and glue three $1\frac{3}{8}$- by 16-inch hardboard spacer strips so that their outer edges are flush with the outer edges of the frame. The glass pane will later fit between the strips with room to spare.

B. Apply glue to the top of the strips and position the 18- by $1\frac{7}{8}$-inch frame over the bottom frame. Fasten frames together using $\frac{3}{4}$-inch-long nails, keeping nails at least half an inch from the inner edge of the opening so as not to interfere with insertion of the glass.

C. Fasten the $1\frac{1}{2}$- by 14-inch plywood mounting strip along one side of the top frame, aligning its long edge along the inner edge of the frame. Attach it to the frame with 1-inch drywall screws, placing the screws about half an inch from the strip's rear edge so that they won't interfere with the glass pane.

D. Attach the metal T-hinges to the front edge of the strip with wood screws, about 2 inches in from either end.

Glass & Frame



A close-up of the hinge placement and reflector attachment.

Step Four: *Assemble the Reflectors*

A. Lay one of the side reflectors against the rear reflector, with the smooth inside surfaces facing each other. Let the bottom corner of the side reflector extend $\frac{3}{8}$ of an inch below the bottom edge of rear reflector. Glue and staple a 12-inch length of nylon webbing to the reflectors, making a hinged joint.

B. Attach the other side reflector to the rear reflector in the same way.

C. Fold side reflectors flat against the rear reflector. With wire cutters or tin snips, cut off protruding corners that extend below the bottom of the rear reflector.

Attaching the reflectors to the top of the glass frame.

Step Five: *Attach the Reflector to the Glass Frame*

A. Evenly position completed glass frame on the oven box top.

B. Place bottom edge of rear reflector against the hinges on the glass frame and mark where holes will go.

C. Drill out the hole marks in the rear reflector and attach to hinges with machine screws, washers, and nuts.

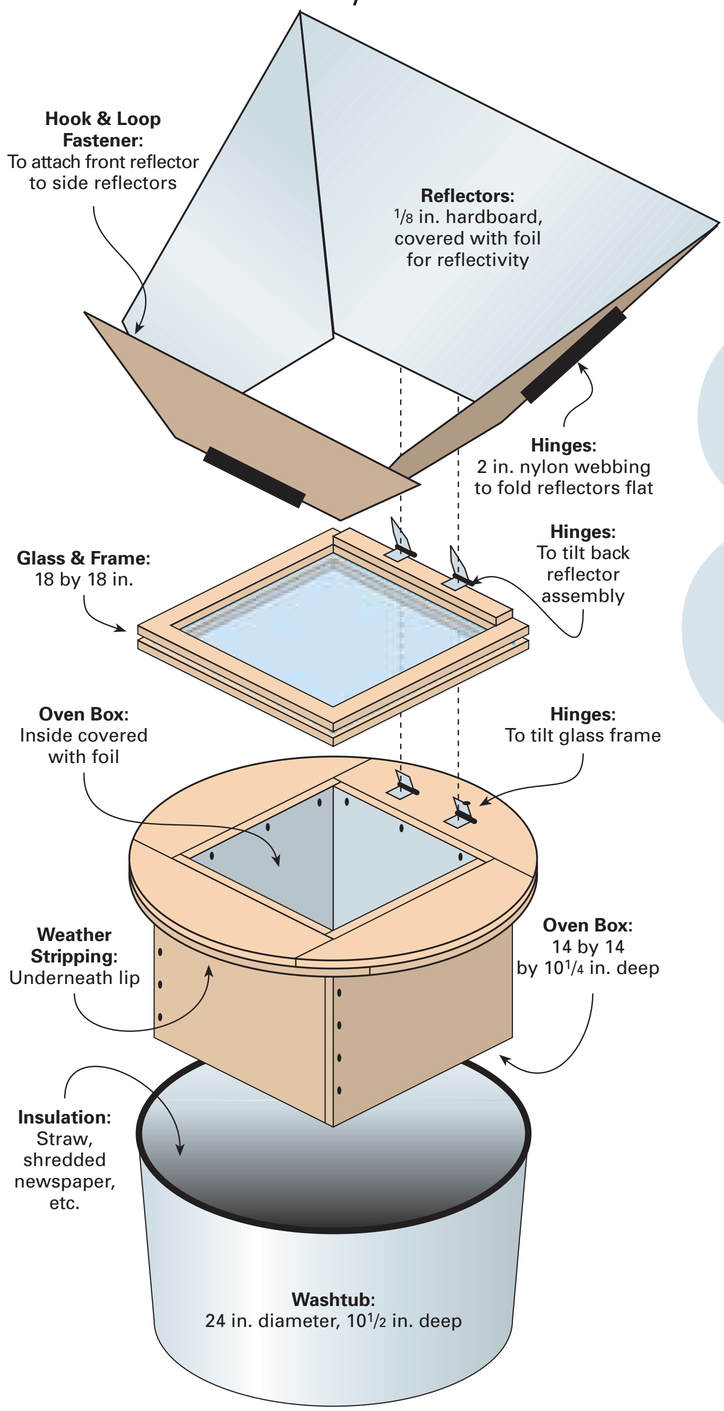
Step Six: *Make the Reflectors Shine*

A. Once the rear and side reflectors fit and fold properly, remove them from the frame.

B. Glue sheets of aluminum foil to the side and rear reflectors. Weight each panel (with a book or other flat, heavy object) and let dry overnight.

C. Glue aluminum foil to the front reflector, taping the edges with plastic packing tape or duct tape. Let dry overnight.

Cooker Assembly



Step Seven: *The Finishing Touches*

A. To the front reflector, glue and staple a web hinge, centering it on the reflector's back, bottom edge.

B. Attach the other edge of the web hinge by gluing it to the front edge of the glass frame.

C. Next, insert the 1 3/8- by 14-inch hardboard spacer strip into the space where the glass will slide into frame. Glue the web hinge, and then staple it to the frame using 1/4-inch staples (3/8-inch staples may poke through the top glass frame and prevent the glass from sliding into place). After fastening the hinge, remove the hardboard strip. (The strip is only used to absorb pressure from the stapler and prevent bending or breaking the frame.)

D. Slide the glass pane into the frame.

E. Adhere two 1- by 4-inch strips of pressure-sensitive, hook and loop closures (such as Velcro), end to end, along the front edge of each side reflector. Apply the matching strips to the front reflector where the side reflectors meet it when they are in the "open" position.

Step Eight: *Put It All Together*

A. Attach the frame to the oven box top with hinges (see photo on the previous page).

B. Place the box–frame in the washtub.

C. Choose an insulation material you can pack between the inner walls of the washtub and around the outside of the box, once it's inserted in the tub. Straw or even shredded newspaper will work.

For a little sweat and about US$80, you can build a simple solar oven.

Materials & Costs

Item	Cost (US$)
Galvanized washtub, 2 ft. diameter	$18.00
AC plywood, 4 x 4 ft., 3/8 in.	13.50
4 Metal T-hinges, 2 in.	6.00
Sticky-backed hook & loop closures, 2 x 4 in.	6.00
Staples, 1/4 in. & 3/8 in.	6.00
Tempered hardboard, 4 x 4 ft., 1/8 in.	5.00
Nylon web strap, 2 in. x 3 ft.	4.00
Glass, 15 x 15 in., 1/8 in. thick	4.00
Wood or paper glue	3.00
Poly-foam weather-stripping, 3/16 x 3/4 in., 12 ft.	3.00
Brads, #18 x 3/4 in., 2 oz.	2.00
Brads, #17 x 1 in., 2 oz.	2.00
Packing or duct tape	2.00
Aluminum foil	1.50
Sandpaper, a few sheets	1.50
12 machine screws, nuts & washers, #8 x 1/2 in.	1.00
12 Wood screws, #8 x 1 in.	0.50
6 Drywall screws, 1 in.	0.10
Insulation (straw, shredded newsprint, etc.)	0.00
Total	$79.00

Get Cooking!

Ironically, during our two-day class, cloudy, cool weather prevented us from cooking in the oven. But you can take advantage of any clear, sunny day to experiment with your solar cooker. Dark, enameled steel cookware works best in the oven, but you can also use glass containers as well, or in a pinch, aluminum. Just put your food into the cookware, place it into the oven, and keep the oven pointed toward the sun. Recipes that call for long, slow simmering are suited to this oven—rice and other grains, and even sweet breads (like banana or zucchini) fare well. For recipes and more information on solar cooking, read *Heaven's Flame* or *Cooking with the Sun* (see Access).

The proud class with their completed washtub cooker (from L to R): DeeAnn Deon-Brewer, Francine Janis, Raymond Handboy, James Mesteth, and Patricia Hammond.

Access

Jim Taulman, Oglala Lakota College, 490 Piya Wiconi Rd., Kyle, SD 57752 • jtaulman@olc.edu • www.olc.edu

Cooking with the Sun, by Beth & Dan Halacy, 1992, Paperback, 114 pages, ISBN 0962906921, US$9.95 from Morning Sun Press, PO Box 413, Lafayette, CA 94549 • Phone/Fax: 925-932-1383 • jdhowell@ix.netcom.com • www.home.ix.netcom.com/~jdhowell/

Heaven's Flame: A Guide to Solar Cookers, by Joseph M. Radabaugh, 1998, Paperback, 144 pages, ISBN 0962958824, US$15 from Home Power, PO Box 520, Ashland, OR 97520 • 800-707-6585 or 541-512-0201 • Fax: 541-512-0343 • subscription@homepower.com • www.homepower.com

"Cooking Under the Sun," by Rose Woofenden in *HP107*

"A Kitchen in the Sun," by Therese Peffer in *HP37*

Quest for India's Renewable Energy Spirit

Eric Fedus

Rama Singh demonstrates a compact solar drier at the Agriculture Tools Research Center in Gujarat.

After working off and on in Central America for a couple years with renewable energy (RE), I wanted to learn more about what was going on elsewhere in the world. I spent two months wandering through the south of India, where seldom an American is seen. I visited numerous RE installations and organizations, for my personal education and to assist the renewable energy consortium—Grupo Fenix—that I had worked with in Nicaragua (see *HP97*).

While the laid-back pace in Central America had soothed my mind, India agitated me, especially at first. I grappled with being a Westerner in an overwhelming environment. I had never seen so many people living in such close proximity and in such an array of conditions. This is a place replete with hypocrisies, poverty, and chaos, and locked down by legendary bureaucracy. Yet it is also a place of strong families, unparalleled hospitality, profound diversity, a depth of history, and a pervading sense of spirituality—a place where renewable energy could serve as hope.

From what I had read and heard from others, I hoped I would find some interesting jewels of renewable energy development here. In the end, of the dozens of places I visited in India, a few caught my attention more than others…

Bangalore—India's Solar Center

As a former computer programmer, I had certainly heard of Bangalore, the city that perhaps most epitomizes India's mastery of technology. Yet I hadn't known that Bangalore is arguably India's solar energy center as well.

Depending on who you ask, anywhere from 60 to 100 or more sellers and manufacturers of solar thermal equipment alone are in Bangalore. Large companies, such as TataBP Solar and Bharat Electronics Ltd., manufacture solar cells here. A multitude of other RE technologies are manufactured here as well, including PV modules, solar streetlights (CFLs and LEDs), solar lanterns, solar cookers, inverters, and charge controllers.

I even heard of solar-powered pesticide sprayers, rickshaws, boats, and power packs. Be it true or false, one

man claimed to me that at the time of Gandhi's revolution, not even a pin could be manufactured in India. When I left this solar town, I had a sense that all that had long since changed.

SELCO—Sustainable Rural Solar Energy

From my own experiences, I knew that extending the grid to rural areas is often prohibitively expensive. Solar electricity can be more cost effective than some of the alternatives, such as disposable batteries and kerosene, used in rural villages. But families usually don't have enough money to purchase a system outright, and donor organizations have a mixed history of success.

Harish Hande tackled these issues when he co-founded the pioneering organization SELCO in 1995. I visited the Bangalore office as well as some of SELCO's installations in the countryside. To date, SELCO has installed more than 30,000 domestic solar-electric home systems while operating in only 3 of India's 28 states. This is no small feat. SELCO is a company that turns a profit and helps local communities by selling solar energy systems in poor, rural areas.

A Scheffler concentrator focuses the sun's energy into a cooking pot at Barefoot College in Tilonia, Rajasthan.

Inside, the sunlight heats a pot or a built-in oven.

SELCO has had to surmount issues of financing, staffing, product quality, transportation, and technology awareness. Over time, they've developed a successful model based on service centers. Although SELCO purchases most system components, they also design and outsource some components to improve quality and lower servicing costs.

Their success has been through a combination of relationships with financial institutions, a strong brand built through offering and guaranteeing quality products and services, a local presence, response to customer feedback, and innovative marketing, such as "demo vans." These vans travel all year visiting villages, to explain the technology and financing options. SELCO strikes me as a good example of a market-based solution for rural electrification.

Kanyakumari—Garden of Windmills

I boarded a rather worn-looking train for Kanyakumari, a spiritual destination in the state of Tamil Nadu. As the train drew near to Kanyakumari, we passed through a virtual garden of wind turbines that went on for miles.

As one of the world's top wind energy producers, India's richest potential lies here in Tamil Nadu, where not

A solar-electric installation in a community in northern Kerala.

A group of students learn to be solar technicians at Barefoot College in Tilonia, Rajasthan.

surprisingly, many wind enterprises are found. In Chennai, I met Mr. Manoharan of Vaigunth Ener Tek, an enterprising small company that has been building and selling wind turbines since 1997. They manufacture systems from 200 W to 25 KW.

In Kanyakumari, I also discovered the Vivekanandapuram spiritual center, with a rural development program and sustainability demonstration and training center called NARDEP. They employ solar and wind energy, as well as vermicomposting, biogas, and solar water distillation. As I traveled India, I discovered that many spiritual centers see community development as a common responsibility, and often create nongovernmental organizations (NGOs) that work with sustainable technologies.

Valsad—Beyond Solar Cooking

"Anything that depends on imports…won't succeed," Deepak Gadhia remarked as he recounted the history of his company, Gadhia Solar in Valsad, Gujarat. I already had spoken with Wolfgang Scheffler, the German inventor of the principal technology Deepak uses, so I had a sense of what he was up to. What I didn't realize is how successful Deepak's company had been building and selling their technology within India.

At a basic level, the Scheffler concentrator appears to be a somewhat flattened parabolic cooker. A simple mechanical tracking system keeps the sun's reflected rays on a pot inside a building, permitting indoor cooking. At a more sophisticated level, by using multiple dishes, the Scheffler concentrator is a powerful steam generation system.

The concentrator can be used for cooking, pasteurization, sterilization, and laundry washing and drying. Ongoing projects include air conditioning, desalination for water and salt production, and even a crematorium. Currently the largest system in the world, a 106-dish system capable of cooking 30,000 meals per day, is located in the southeastern state of Andhra Pradesh.

I left Valsad with a sense that Deepak was right. Reliance on foreign nations will not make a strong India. Perhaps it will need friends, but ultimately, India's success will come from within.

Barefoot College

Perhaps their Web site says it best, "The Barefoot College is a place of learning and unlearning. It's a place where the teacher is the learner and the learner is the teacher. It's a place where *no* degrees and certificates are given because in development there are no experts—only resource people."

SELCO PV System Costs

System Size	Cost Rupees	Cost US$
2 CFL system (incl. 20 W module, 30 AH battery & 5 A charge controller)	12,000	$262
4 CFL system (incl. 37 W module, 60 AH battery & 10 A charge controller)	18,500	404

Vaigunth Ener Tek Wind System Costs

System Size	Cost Rupees	Cost US$
200 W (w/o installation)	36,000	$786
500 W (w/o installation)	53,000	1,157
1 KW (w/o installation)	93,000	2,030
5 KW (w/o installation)	295,000	6,438

To reach Barefoot College, I traveled to the desert state of Rajasthan, a culturally conservative, poor, and highly illiterate state—in a sense, a place ripe for the birth of Barefoot College. The NGO, which serves as a model for about twenty other affiliated organizations around India, is not a college in the traditional sense at all. Rather, it works with people in nearby communities on projects of income generation, health centers, rainwater harvesting, and much more.

The campus is fully electrified by PV systems, and has an innovative solar technician training program. "Drop outs, cop outs, wash outs," as I have heard founder Bunker Roy graciously say, are invited from their villages to spend six months at the campus learning to be technicians, but with no promise of a degree. Why?

It's about helping people help themselves without disturbing the balance in a community. Degrees often lead people away from their communities. Barefoot College technicians have returned to their communities and have electrified hundreds of schools and thousands of households. Despite current market-oriented trends in development work, Barefoot strikes me as an organization judiciously, effectively, and respectfully using its donor resources to help communities sustain themselves.

The Coming Years

After visiting dozens of organizations, I began to realize how vast India is, and how little of it I would see in two months. The diversity and ingenuity of organizations I encountered was fascinating. I now appreciate that India is a diverse and complex environment with significant challenges lying ahead. Problems range from issues of electricity management, including high energy losses and grid instabilities, to massive population, urban pollution, and rapid growth in already overcrowded cities, caused by an influx of people from rural areas.

When I left India, though, I left with a sense of awe both for what has already been done and for how much further there is yet to go. I sense a future in which India will play a strong role in the harnessing of the world's potential.

Access

Eric Fedus, 369 E. Shore Dr., Colchester, CT 06415 • 860-537-1100 • efedus@hotmail.com

TataBp Solar • www.tatabpsolar.com

SELCO India • www.selco-india.com

Vaigunth Ener Tek • www.v-enertek.com

Gadhia Solar • www.gadhiasolar.net

Wolfgang Scheffler • www.solare-bruecke.org

Barefoot College • www.barefootcollege.org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check out the website:
http://egov.oregon.gov/ENERGY/RENEW/Solar/Tour/2006/TourHome.shtml

Code Q&A

John Wiles
Sponsored by the U.S. Department of Energy

Q I want to give my customers the best possible system for the least cost. Since time is money, I worked up a couple of shortcuts that will save me some time on solar-electric (photovoltaic; PV) installations. I usually mount my modules in rows, in a portrait configuration. The module manufacturers place the grounding points on the long sides of the modules, where they are difficult to reach to connect wires. I have been drilling holes in the short sides of the modules and installing lay-in lugs, which are very easy (and fast) to wire. At the end of each module string, I switch to a THHN conductor in a junction box, and use conduit through the attic and down to the DC disconnect. I usually just cut off the Multi-Contact (MC) connector from the first and last modules in the string, and use a split bolt or a crimp-on connector to connect the bare module wire to the THHN. What's your view on this?

A I applaud your desire to make a quality installation and keep the costs as low as possible. Unfortunately, some problems arise from your time-saving techniques.

First, drilling the module frames may void the manufacturer's warranty. This is especially problematic if you are drilling a new hole at a location other than the marked grounding point. Underwriters Laboratories (UL) has evaluated the module grounding *only* at the marked points, and other points may not provide adequate grounding. Furthermore, other points on the module frames may not be thick enough to provide the required two full-contact threads for a good electrical connection. For those rare instances where the module grounding hardware and/or instructions prove difficult to use, you might want to review the *Code Corner* on PV module grounding in *HP102*. In all cases, please contact the module manufacturer and see what their position is on module modifications, grounding, and warranties. Some of them have technical notes on this subject.

I am working with Underwriters Laboratories (as a member of the Standards Technical Panel) on UL Standard 1703 for PV modules to clarify the requirements and methods for PV module grounding, and to encourage module manufacturers to give installers more and better options for module grounding. For example, modules with conduit-ready junction boxes could have a third, copper-compatible terminal in the J-box for grounding, just like most other electrical devices. Modules with pigtail leads and MC connectors could have a third lead added for the equipment-grounding conductor, and studs or nuts that are copper compatible could be pressed into the module frames. As a minimum, module grounding points could be provided on both the short and long sides of the module frame. If these options appeal to you, write to the module manufacturers. There is nothing to prevent them from offering these options today.

Cutting off the MC connectors is also a warranty issue for some module manufacturers. When the manufacturer objects to cutting off the connectors, the easiest thing to do is buy pre-made cables with MC connectors attached. Another option is to buy an MC connector tool, take the factory training, and make your own connector–cable assemblies.

Several effective splicing devices can be used where proper strain-relief has been provided for each cable. They include wet-rated, twist-on connectors; split bolts (heavily taped); and several other types of insulated splicing blocks made by various manufacturers.

Any and all exposed metal, including junction boxes, must be properly grounded, and all metal conduits must be properly terminated and grounded at each end to other grounded equipment.

Q I have, on previous PV installations, connected the MC cables continuous from the last module in the string, through the J-box on the roof to the DC disconnect. I do this to avoid having a connection at the J-box (less chance of failure), but it means that I am running the USE-2 wire in conduit (usually 3/4 inch) to the disconnect. Is this a "proper use" of USE-2 wire? If not, what is your preferred method for splicing in the J-box and should the grounding wire be landed there?

A Type-MC cable in the *National Electrical Code (NEC)* refers to metal-clad cable; this may be an indoor- or outdoor-rated cable depending on the actual construction and marking on the specific product. If you mean single-conductor cables with MC connectors, that is something entirely different. Cables with only the USE-2 marking may *not* be run inside any building (even in conduit) because they have no flame retardant. Cables marked USE-2/RHW-2 have the proper flame retardants and can be exposed in outdoor locations for module interconnections, as well as run in conduits, both outdoors and indoors.

Any conduit in the building must be a metal conduit like EMT, not a plastic conduit, and that use is permitted only under the 2005 *NEC*, not the 2002 *NEC*, which is still in effect in many areas.

Q I have read through the section on string fusing in your *Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices* manual, but am still a bit confused about this topic. I tried to draw a diagram showing the various scenarios, but still did not totally understand the theory. I have tried to find diagrams illustrating this, but have been unsuccessful. Do you know of any? Also, isn't it possible that the faulted string could add backcurrent, depending on the fault location in that string? I would like to understand the theory behind this.

A Fusing of any PV module or conductor is required when potential backfed currents from all *external* sources exceed the reverse current rating of the module (listed on the back of the module as the maximum protective fuse) or the ampacity of the conductor. Currents generated *in* a string of modules are not counted in this calculation, since both the module and the conductors are, by design, capable of handling all forward currents. In the simple case, the sum of all external currents (typically 1.25 Isc from each external string with no feedback from the inverter) must be less than the module maximum protective fuse. If the external currents are larger than the fuse rating, a series fuse will be required on each string of modules. For more details and theory, see Appendix J in the newest version (1.3) of the *Manual* (see Access and the SWTDI Web site).

Q I used a braided tinned copper (flat) grounding wire on a system a couple of years ago and found it very nice to work with. I am unsatisfied with the typical ground method (clamps and #6 bare), as I feel that there are too many connections to come loose (especially at the clamp). When fastened directly to the module with a stainless steel #10-32 screw and a stainless steel star washer, the braided wire is superior. Do you have any experience with this? How should I size this wire? This type of wire has an AWG "size" and an ampacity rating, but the corresponding size to #6 does not have the ampacity of #6.

A I have no experience with tinned braided conductors and do not know if they are suitable for use in contact with aluminum module frames, nor do I know if the material is suitable for outdoor applications. These braided grounding straps are used to ground electronic equipment and are usually installed in a dry, indoor environment. While some inspectors require #6 equipment-grounding conductors for physical strength, the code requirement is usually a smaller conductor sized at 1.25 Isc. These smaller conductors, such as #12 or #10, can usually be adequately attached to the module using the hardware provided. Uninsulated conductors don't have ampacity calculated in the same manner as insulated conductors because there is no insulation to worry about overheating. However, the *NEC* requires that you use the ampacity associated with the same-size insulated conductor.

A Question for You

Have you ever had any electrical or electronic device or appliance damaged when connected to a modified square wave inverter (also called a modified sine wave inverter)? Such devices or appliances might include light dimmers, laser printers, copiers, and battery chargers for power tools.

If so, please send me the manufacturer and model number of the inverter, and as much information as you can provide about the damaged device or appliance (name, model number, date, damage, etc.). I will forward the information to Underwriters Laboratories (UL). UL is concerned about listed PV inverters damaging other listed equipment in common use. They may consider tightening the specifications and requirements on these inverters to reduce the possibility of equipment damage.

Other Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write me at the location below. See the SDTI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

John C. Wiles, Southwest Technology Development Institute, New Mexico State Univ., Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003 • 505-646-6105 • Fax: 505-646-3841 • jwiles@nmsu.edu • www.nmsu.edu/~tdi

Sandia National Laboratories, Ward Bower, Sandia National Laboratories, Dept. 6218, MS 0753, Albuquerque, NM 87185 • 505-844-5206 • FAX 505-844-6541 • wibower@sandia.gov • www.sandia.gov/pv

The 2005 *National Electrical Code* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA) • 800-344-3555 or 508-895-8300 • www.nfpa.org

Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices, a downloadable 144-page PDF manual • www.nmsu.edu/Research/tdi/public_html/Photovoltaics/Codes-Stds/PVnecSugPract.html

2008 *NEC* Proposals PDF • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf

Standards, Knowledge & Integrity

A Basis for RE System Performance

Don Loweburg

In addition to the solar resource available at a given site, many factors can affect overall system performance, the most important being component performance, system design, and installation integrity. In the past several years, extensive performance reviews of installed PV systems have been conducted, revealing systems that are "underperforming"—producing fewer kilowatt-hours (KWH) per year than expected compared to the module manufacturer's ratings. Besides reflecting poorly on the industry as a whole, this issue is especially troublesome for installers, whose reputations and livelihoods rely on providing solid performance predictions for their customers.

Module Performance

The International Energy Association (IEA) reports that PV module underperformance has been a primary reason for poor system performance in the past, though they also note that there has been recent improvement.

To address this, Chuck Whitaker, a consulting engineer at BEW Engineering, has recommended that the PV module rating method be changed to one that rates PVs at their *minimum* output, rather than at standard test conditions (STC), which are conducted at an air and cell temperature of 77°F (25°C). He also has proposed that modules be rated to international standards certified by PowerMark Corporation, a nonprofit certification agency.

"Currently, modules sold into California are provided with a power rating tolerance of up to plus or minus 10 percent (though there has been recent improvement by some manufacturers)," he says. "This means that a module with an STC nameplate rating of 150 watts could have an actual rating between 135 W and 165 W, based on manufacturer factory testing. Due to market pressure and other circumstances, the actual rating of an individual module rarely meets, let alone exceeds, the nameplate rating—thus measured system performance continues to fall short of expectations. European procurements typically require a tighter tolerance (plus or minus 3 percent) than is normally provided in the United States."

In addition to lower-than-expected system performance, another issue is related to the systematic overrating of PV module output—the fact that PVs are sold to system integrators on a dollar-per-watt basis. Using Chuck's example above, installers would be charged for a 150 W PV module, even though the real-world output may only be 135 W. Since system installers and designers are liable for their systems achieving specified performance levels (as they should be), they must factor in and design arrays with this overrating in mind to arrive at a desired system output.

The lack of a U.S. module standard that reflects more accurate real-world performance is not due to a lack of effort. Many organizations have been working on standards and equipment certification for the past decade, including Interstate Renewable Energy Council (IREC), Sandia National Laboratories, PowerMark Corporation, and the Florida Solar Energy Center (FSEC).

A report from IREC says that over the past ten years, efforts have been made "to harmonize U.S. and international standards on PV product certification and to replace U.S. standards with international standards." Although the report also says that success has been limited, continued support of these efforts is essential because "uniform standards and uniform guidelines for effectively applying these standards serve the best interests of both consumers and the photovoltaic industry."

In general, modules supplied to Europe and Japan more accurately comply with their ratings than those sold in the United States. The German and Japanese markets have demanded this by having established more accurate rating standards. Until the U.S. market establishes a more accurate power rating standard, it will remain a venue in which module manufacturers can sell "underperforming" modules.

Inverter Performance

An inverter's function is to efficiently harvest the direct current (DC) energy supplied by a PV array and transform that energy into an alternating current (AC) suitable for onsite loads or export to the grid. Because the DC energy input varies significantly over the course of a day, an inverter must be efficient over a wide range of power and temperatures. Additionally, because PV array output can change rapidly due to passing cloud cover, an inverter's maximum power point tracking (MPPT) must be nimble but stable.

With hundreds of thousands of inverters installed in grid-tied PV systems worldwide, there's clearly a market for these products. However, no standardized method or testing body has existed to measure inverter performance. Now, Sandia

National Laboratories has developed an inverter testing method that addresses these performance issues.

So far, the California Energy Commission (CEC), the organization that oversees the state's solar incentive programs, has incorporated many elements of Sandia's inverter rating protocol. Because the California PV market accounts for more than 50 percent of the U.S. market, the CEC has a tremendous opportunity to improve system performance numbers by establishing meaningful and accurate performance standards for critical system components.

Intelligent Design

Smart grid-tie PV system design involves matching accurately rated components, understanding the local solar resource, and integrating both of these elements to achieve a specific annual energy output. Here, a designer's knowledge is crucial. Though components (inverter and PV modules, for instance) may be accurately rated, they could still be mismatched, resulting in less-than-ideal system performance. A designer must also understand high and low PV string voltage, upper and lower temperature limits, and module output voltage as a function of temperature. In addition, siting issues—including shading, array orientation, mounting angle, and mounting structure (roof, rack, building integrated)—affect system performance. Understanding these variables is paramount if maximum system performance is to be obtained.

Numerous educational programs, such as those offered by Solar Energy International (SEI), teach this information. Additionally, the North American Board of Energy Practitioners (NABCEP) certifies PV installers, based both on demonstrated field experience and the ability to pass a written examination covering the theory and practice of PV design and installation. Proper training and installer certification can together raise the bar, resulting in better system design, yielding better system performance.

Installation Integrity

The final element necessary in achieving maximum system performance is installation integrity. These nuts and bolts issues include using proper roof mounting and flashing methods, leak-proofing, and specifying appropriate conduit, wire size, wire type, and approved cable termination. No less important is designing a professional layout of conduit, wireways, electrical panels, and junction boxes. Even when components are properly rated and the system design is good, poor installation can result in both unsafe and unsatisfactory system performance.

There is a growing demand for accountability with respect to system performance. This is desirable for customers, incentive program administrators, and qualified installers who are concerned about how underperforming systems affect the industry. Given accurately rated components and a knowledgeable design approach, coupled with code- and safety-compliant installation methods, a qualified PV system installer should be able to design and install high performance and long-lasting systems that meet their predicted outputs.

Access

Don Loweburg, IPP, PO Box 231, North Fork, CA 93643 • 559-877-7080 • i2p@aol.com • www.i2p.org

BEW Engineering • 925-867-3330 • www.bewengineering.com

NABCEP Certification • www.nabcep.org

PowerMark Corp. • 602-955-7214 • www.powermark.org

Research Reports:

International Energy Agency's PV systems performance studies & database • www.iea-pvps.org/

Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems • www.bewengineering.com/docs/InvertrTestProto_041014.pdf

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Sandia National Laboratories Photovoltaic Systems Research & Development • www.sandia.gov/pv/

The Yawning Maw
of Energy Transmission

Michael Welch

Much has been said about the Energy Policy Act of 2005 (aka the Energy Bill), but little has been heard about some "minor" points included in the bill that could have major impacts on the environment, such as global warming, habitat fragmentation, stream pollution, and viewshed and wilderness destruction, as well as impacts on the future of renewable energy (RE).

One of the things that made it into the final Energy Bill is the use of public lands by energy companies to transport their product from its place of production to its point of consumption. The bill requires federal agencies to designate new right-of-way corridors on federal lands for electricity transmission and distribution facilities, and oil, gas, and hydrogen pipelines. While there is still some demand for new pipelines, demand for electrical transmission lines is much greater—unfortunately, they come with coal-fired power plants to feed them.

King Coal

There is a *lot* of coal in the United States. Some say there is so much that we do not have to worry about electric power supply for the rest of the century. In fact, with the passage of the Energy Bill, lots of tax dollars are being spent on developing "clean coal" technologies. (This is doublespeak that really means "somewhat cleaner" than the old technologies.) The coal industry is pushing hard for more power plants to supply our needs, and is even hopeful that coal will someday provide liquid and gaseous fuels for other uses like home heating, hydrogen generation, and even producing a diesel-like fuel for vehicles.

Montana alone, sparsely populated as it is, has five new coal plants in various stages of proposal or construction, with the possibility of more waiting in the wings. Are Montana's energy needs so great it *needs* five new power plants? Heck no—the power is needed in the far-western states. But the coal is in Montana, and the companies want to build the plants near their fuel sources. No fewer than twenty new coal power plants are in various stages of actualization in the interior-western states. All have hopes of delivering electrical energy to other areas of the nation. Christopher Childs of the North Star Chapter of the Sierra Club says about 50 coal plants are planned in the Midwest, and 140 nationwide.

But only so much capacity exists in present transmission lines and facilities. Part of the rush for building new power plants is because the first plants to go online will have dibs on the excess existing line capacity. Ones that come online later may be forced to deal with increasing the capacity of already-existing transmission facilities or building new transmission, which often means running new power-line corridors through public lands. And that is where the Energy Bill comes in, directing the federal agencies to work with stakeholders to propose and push for new transmission corridors, mostly into the far-western states.

Environment Disturbed

What is of concern is the impact on local environments and global warming. The new coal plants under consideration will have somewhat lower emissions than older plants, but will still release volumes of particulates and other local pollutants, as well as contribute to greenhouse gases and acid rain.

If we are to avoid the catastrophic climatic effects predicted if global warming continues unfettered, we must move forward with RE and non-fossil fuel burning technologies. Coal makes up just over 50 percent of U.S. electricity production, yet contributes nearly 85 percent of electricity production's carbon dioxide emissions. (An interesting aside: The Energy Bill—and its support of the fossil fuel industries—was passed shortly before politicians and the major media began earnestly discussing the effects of climate change and what we could be doing about it, and

High-voltage transmission lines cut a swath through a scenic Northwestern forest.

Source: http://corridoreis.anl.gov

just weeks before the global warming-enhanced Hurricane Katrina made landfall on the Gulf Coast.)

But the lesser-known environmental problem involves a toll from building new transmission corridors. Getting electricity from the interior to the far-west states means significant transmission losses, and slashing through some of the most breathtakingly beautiful and pristine public lands in the West, including areas that could qualify as wilderness. Building these transmission towers, and stringing and maintaining the lines also calls for constructing access roads into remote sites.

Is cheap energy worth cutting large swaths through some of our remaining wilderness? My first response was, "No way!"—especially considering that relying more heavily on cheap coal energy will make it still harder to switch to decentralized, local renewable energy.

Enter Wind

But coal is not the only cheap and plentiful energy source in the interior states, and the coal industry is not the only one pushing for more transmission capacity through public lands. The wind energy that many of us tout as an important solution to dirty fossil fuels, nuclear chain reactions, and global warming is plentiful in that region.

The wind industry has wisely taken advantage of the "easy pickins"—the high-wind sites near existing transmission lines. Their next options are milder-wind areas with existing nearby transmission lines, and then high-wind sites that require new transmission lines to deliver the energy where it is needed. For sure, that 50,000-acre cattle ranch in central Wyoming won't consume all the energy from one commercial wind generator, let alone the 50 that might be sited there—the energy must be delivered to markets that can use it.

For many RE advocates with strong environmental concerns, the idea of building new transmission corridors is worse than unpalatable. But is bolstering the wind industry in these places important enough to justify the environmental impact of the new transmission lines needed to carry that energy?

Certainly, adding wind energy into this issue makes the choice less cut and dried, but I think the answer lies in examining each proposed corridor individually. We need to accept or reject each based on its own environmental impacts—and weigh this against its potential merits.

Unfortunately, the process set up by the Energy Bill is going to make that difficult. The federal agencies involved, including the U.S. Department of Energy, the Bureau of Land Management, and the U.S. Forest Service, in cooperation with the Departments of Commerce and Defense, have been jointly mandated to designate the corridors, without having to first determine whether or not the corridors are actually needed or desirable. As the first step toward the mandate, the agencies have already finished with public scoping sessions to get input into siting corridors, determining the environmental impact of the options, and identifying other possible problems. The energy industry, including the American Wind Energy Association, has weighed in heavily during these scoping sessions, and the West-wide Energy Corridor Programmatic Environmental Impact Statement (PEIS) will be based on that input when it comes out in September or October, with the final EIS to be completed by August 8, 2007. All corridor sitings must still gain regulatory approval and must be able to meet all the other normal regulations and laws, despite the mandate for siting.

Environmental groups are trying to figure out how to track the individual corridors in question, and how to choose which ones merit challenging. According to Christopher Childs, "Transmission to me is this sort of yawning maw into which one can imagine disappearing in the quest for information and comprehension." Activists can use the corridor siting process as one means of fighting additional coal plants in their communities, but caution is called for, as many transmission lines will be carrying both coal and wind energy. Folks working on these issues also need to remember that improving demand-side management by increasing efficiency will go a long way toward supporting efforts to stop more power plants.

We must find the way to ferret out the good from the bad, and figure out how to effectively voice our opinions and support for decentralized RE, while putting the brakes on the coal industry to let centralized wind take its place. Time will soon tell what corridors the government is planning, and what the impacts of each will be. Each of us in affected areas must take a good look at what is being done, and decide in each instance whether to challenge or let go of the issue.

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Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95518 • 707-822-7884 • michael.welch@homepower.com • www.redwoodalliance.org

Sierra Club, North Star Chapter • 612-659-9124 • www.northstar.sierraclub.org/campaigns/air/coal/

Western Resource Advocates • 303-444-1188 • www.westernresources.org

West-wide Energy Corridor Programmatic Environmental Impact Statement • http://corridoreis.anl.gov/

Solar Collector

Ian Woofenden

Derivation: "solar" is from Latin solaris, *of the sun; "collector" is from Latin* colligere, *to gather together.*

Modules and collectors are two entirely different technologies that both make use of the sun's energy. Solar-electric (photovoltaic; PV) modules produce electricity, and solar *collectors* heat air or water. Residential solar collectors come in three categories—pool collectors, domestic hot water collectors, and hot air collectors.

Pool collectors are usually either rows of black plastic pipe or molded plastic, or synthetic rubber mats with small tubes integrated into the mat. These collectors do not generate high-temperature water, but that's not their job. Pools only need to be kept at about 80°F (27°C) for comfort. Heating to this relatively low temperature is what these simple collectors do best. A rule for system sizing is to use roughly the same collector area as your pool's surface area.

A flat-plate solar domestic hot water collector (left) and an evacuated tube collector (right).

These roof-mounted polypropylene solar pool collectors offer a fast payback and easy installation.

Courtesy www.solarexpert.com

A pump circulates water between the pool and the collector when sensors indicate to a controller that the water temperature in the collector is higher than that in the pool. Solar pool heating systems are some of the most cost-effective renewable energy systems available, perhaps only beaten in simplicity and effectiveness by a person getting warmed up by lying in the sun.

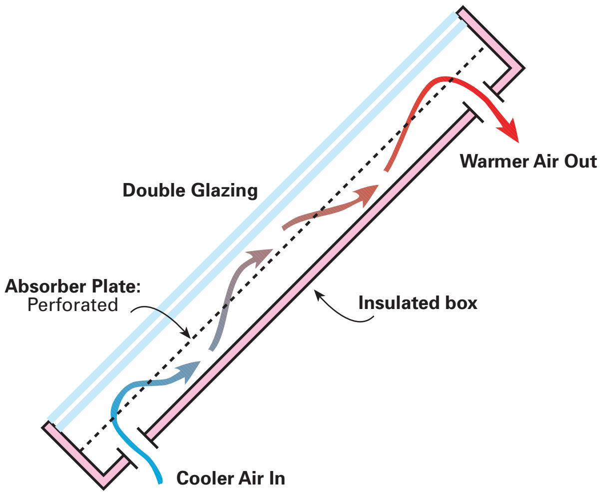
Solar domestic hot water (SDHW) collectors come in two types—flat plate and evacuated tube. In residential systems, both are designed to heat water for domestic uses, such as showering, and dish and clothes washing. They also can be used in conjunction with radiant floor space-heating systems.

Flat-plate collectors are simpler and less expensive than evacuated tube collectors, but larger, bulkier, and heavier for the same output. They typically consist of insulated metal boxes with glass tops, with a grid of tubes bonded to an absorber plate inside.

Evacuated tube collectors generally use double-walled glass tubes with a vacuum between the walls. A selective surface on the inner tube allows the sun's radiant energy to enter, but not so easily exit. The vacuum provides excellent insulation. Inside the tube, you'll find either water or a copper absorber plate filled with a heat-transfer fluid.

With either type of collector, heat is transferred from the collector to an insulated storage tank via pumps or by thermosyphon (passive transfer). Pumps can be powered directly by a PV module, or by AC or DC electricity from other sources.

Cutaway View of Solar Hot Air Collector



Solar hot air collectors look very similar to flat-plate hot water collectors. But instead of containing plumbing, the insulated box has a suspended black absorber plate that allows air to circulate around it. Openings in the box accept ducting that is routed through a home's roof or walls, and into the living space.

Sensors and controls operate a blower, which turns on when the collector's temperature is higher than the home's temperature. Colder air from inside the home is pulled into the collector, and heated air from the collector is vented into the room.

Heating your home, pool, or domestic water with the sun's energy can be cost effective and rewarding. After insulating your home and incorporating any passive solar design features, solar heating is an excellent next step. In fact, producing solar heat is generally more cost effective than producing solar electricity. There's no shortage of sunshine—you just need to invest in the collectors to harvest the sun's energy and use it!

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Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com

Anti-Septic Adventure

Kathleen Jarschke-Schultze

City folks send wastewater down their drains and to the sewers without a second thought. But when you live in the sticks, you usually have a septic tank. Typically, it's a big concrete or steel tank buried in the yard that might hold as much as 1,000 gallons of water. Wastewater flows into the tank at one end and leaves the tank at the other.

In the tank there are three layers. Anything that floats rises to the top and forms a layer known as the scum layer. Anything heavier than water sinks to form the sludge layer. In the middle is a fairly clear water layer. This body of water contains bacteria and elements like nitrogen and phosphorous, and is largely free of solids. As new wastewater enters the tank, it displaces the water that's already there. This water flows out of the septic tank and into a drain field or leach lines. A drain field is made of perforated pipes buried in trenches filled with gravel.

Meanwhile, Back at the Ranch

Although my husband Bob-O and I knew what a septic system was, we did not know *where* ours was. When we bought our house in 1990, the couple we bought it from had lived in it years before. Then they had rented it out. They decided they did not like being absentee landlords and sold to us.

Before we bought the house, we asked a lot of questions about it and they answered as best they could. But one question they could not answer was the location of the septic tank. They freely admitted that they had never had it pumped and neither had the owners before them. They could not even garner a good guess as to where it was.

Septic Snaking

Eventually, the plumbing clogged. I drove to town and rented a fairly hefty hand-crank drain snake. It was fifty feet long, and I had to pay out the whole length to clear the clog. This meant our septic tank was at least fifty feet from the toilet.

Through the years this scene repeated itself. The line would clog and we would snake it clear. I always worried that a clog would happen that we could not clear—and then how would we find the septic tank? I asked Jerry at the rental store how I could find it.

First, he asked if I could see the pipe leaving the house. I could, I said, in the crawlspace under the house, where all my plumbing adventures seem to take place. So, he says with authority, the pipe leaves the house in a straight line to the septic tank. This information does not make me happy. That would put the tank either under our woodshed or under an eight-module Wattsun dual-axis tracker.

The dreaded day finally came. We could not snake the toilet line clear. We had to figure out where the septic tank was. It was beyond critical. On the Salmon River, we had a nice, two-holer outhouse, but here on the creek we have none. We did, however, have a five-gallon bucket, some sawdust, and a backhoe. Bob-O was considerate enough to buy me a toilet seat for the bucket. As it was springtime, using our emergency facilities was not unpleasant—just unhandy. But even though we cannot see any neighboring homes in our canyon, I still felt exposed.

Septic Sleuthing

So I started calling septic-tank pumping companies to get pricing and scheduling options. Everyone had a hard time believing we had lived here for fifteen years and had never had the septic tank pumped.

The guy at the first place I called balked when he found out how far in the sticks we lived. "I'll tell you how I would try to find the tank," he offered. "First, just go outside and look at the land around your house. Just relax and look at it. Sometimes you can see subtle changes in the ground or lawn, like a slight depression or a line of ground a little deeper than the rest, running away from the house foundation."

"Oh," I said brightly, "you mean be Zen about it."

There was a long pause, then, "Yeah, lady, be *Zen.*" He went on to tell me a second method. This involved getting a piece of rebar and shoving it into the ground every so often, listening for the end to clunk onto the concrete tank.

"When did you say the house was built?" he asked. After I told him 1964, he said, "Well, back then they might have put a metal tank in there. If you hit the metal tank with the rebar, it will most likely go right through, and when you pull it out, it will smell bad. What are you going to do when you find it?"

I told him that my husband had a backhoe and we were going to dig it up. He warned me that if it turned out to be a metal tank we should be extra careful digging, as the whole tank could collapse with rust and age. This did not sound good to me.

I went outside and tried being Zen. It didn't work. There is no flat ground around our house.

I hired the next guy I called. I would have to wait two days, but he would come out and map our septic line to the tank. It would set us back US$350, but it had to be done, and quickly.

He came out and shoved a line down the toilet. There was a light and camera on the end of the line, and we could *see* inside our septic line. When he had it down there a-ways, he went outside with something that looked like a metal detector. He waved it around and found the camera end through the dirt. We started drawing a map, working slowly and stopping to map the line often. It did not run straight from the house. Just outside the foundation of the house it took a 90-degree turn and headed downhill.

Everything was going—dare I say—swimmingly, when he encountered water. Well, liquid of some sort. He could not get a good reading from the sensor anymore. He was sorry, but that was as far as he could map. Before he left, he gave us his best guess as to where we might start digging.

Diggin' It

We had decided it would be wiser to dig with shovels rather than the backhoe. We marked off a 4-foot-square area and started digging. Eureka! We found it! Our square overlapped the metal hatch plate by 2 feet. And, joy of joys, it was a thick, concrete tank. It was positioned halfway between our Genny DeeCee and the "yard bomb" (propane tank). We enlarged our hole and uncovered the hatch. Bob-O used a crow bar to pry it up. Yep, it was full—and disgusting.

The next day we hired a septic tank pumper to clean out the tank. It was the Zen guy's brother. He asked me, "When was the last time this was pumped?" I replied, "Never, to our knowledge." He said he believed me. We were charged a little extra, as it was a might tougher to get all the old stuff out. Three hundred dollars, and an hour and a half later, it was done.

It all turned out okay in the end. We are slowly replacing the old cast-iron sewer line with new plastic pipe and clean-out fittings. I have drawn a map of the sewer line and septic tank, and stapled it to our deed. We have marked the center of the tank hatch plate. Now, I'm not Anti-Septic, I've just had all the adventure I want on that score.

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Kathleen Jarschke-Schultze is looking for the best method to germinate carrots in her garden in northernmost California. c/o Home Power Magazine, PO Box 520, Ashland, OR 97520 • 800-707-6585 • kathleen.jarschke-schultze@homepower.com

Mailbox

Sustainable Motivation

My 4-year-old daughter crawled in bed with me at 3 a.m. Once awake, I couldn't help but think about how to provide sustainable energy for our home, which I am now rebuilding (down to studs; all new systems). The situation of peak oil and the dramatic changes that are coming in energy costs, not to mention how this will change our economy and lifestyle, is what really got me up and searching on the Web to see what I can do to ensure my family's future in our home.

Scott Russell's article on home solar-electric system costs in *HP109* provided a good grounding and basic sense of direction to follow. I'm not able to go back to sleep yet, but your free article provided some peace of mind. I'll start my subscription to *Home Power*. Thanks again—keep writing!

Roberto Miller •
Mountain View, California

EV Death

Shari Prange's sidebar, "Death of the Production EV," in "My Solar-Electric House & Car," (*HP113*) is a gross oversimplification as to why the pure electric vehicle (EV) has never made it into production here in the United States as in Japan. As a physicist and a lifelong student of energy, I'm concerned that your readers may come away from this article with a wrong impression. However, understand that I'm not against EVs. I drive a hybrid and think that the grassroots EV community is doing great work, particularly when the vehicles are recharged by renewable energy sources.

While it is true that Detroit was never enthusiastic about the EV, and fought the California Air Resources Board mandate, the laws of physics, not failure of "will," doomed the EV. If recharged with the grid, not by means of renewable sources, the overall well-to-wheel energy efficiency of an EV is a net loss to the environment compared to the internal combustion engine (ICE) vehicle. The overall efficiency of a gallon of fuel burned in an ICE is greater than that of a gallon of fuel burned in a utility power plant.

Each time there is an energy conversion process, there is an inherent efficiency loss for the specific process. For the EV, the path is long and complex. Consider how many conversion process there are: fuel combusted to produce steam, steam turbine losses, generator losses, voltage step-up losses, long-range transmission line losses, voltage step-down losses, local transmission line losses, battery charging losses, battery efficiency losses, and finally electric motor efficiency losses. When added up, these losses exceed the single conversion loss of burning that gallon of fuel in an ICE.

It's worse than that. Because the efficiency is lower, the net creation of greenhouse gas on the planet is higher. While it may result in less pollution in downtown Los Angeles, a higher amount of pollution must be produced somewhere else, say the Navajo generating station in Page, Arizona, for example. It should also be noted that the use of hydrogen is not the answer either. Hydrogen should be regarded as an energy carrier and not an energy source, since there is no "free" hydrogen—it takes energy to produce hydrogen fuel.

This takes us right back to the root problem: the need for conservation and the development of clean energy sources. For this, we need to develop the will to solve the problem. It's hard to believe that a country that can start from scratch and put a man on the moon in less than ten years cannot apply the best scientists and engineers to come up with meaningful solutions to the energy problem just as quickly.

Ed Marue • Tucson, Arizona

Hi Ed, If the laws of physics doomed the EV, why didn't the manufacturers present this information to CARB, which would have certainly dropped the Zero Emissions Vehicles (ZEV) mandate? The manufacturers never once claimed they were canceling their EV programs due to the vehicles' inability to meet efficiency or emissions standards. Instead, they pleaded economic duress and lack of market interest. These excuses were supported only by cooked books that exaggerated manufacturing costs and by a strangled "marketing" program. How can a vehicle possibly gain wide acceptance if it is almost unobtainable?

The numbers I have from the U.S. Department of Energy indicate that well-to-wheel efficiency for an EV is about 17 percent, compared to 11 percent for a gas (ICE) car. That represents a 55 percent increase *in efficiency, and* includes *all the losses along the way. In other words, extract two barrels of oil from the ground, and refine one into gasoline and use the other to generate electricity. Of the total (100%) potential energy available in each barrel of oil, 17 percent actually makes it to the wheels of the electric car, while only 11 percent makes it to the wheels of the gas car. While refining gasoline is much more efficient than making electricity at the power plant, the greater efficiency of an electric motor in the car over a gas engine more than tips the balance. I can provide efficiency numbers for each step of the process.*

Of course, the electricity does not need *to come from oil, or coal, or any specific source. The efficiency and emissions reduction is even better if the car is charged from a home renewable energy system.*

"Shifting the pollution elsewhere" is another myth. Electric cars are primarily charged overnight, when utilities have surplus capacity. The existing utility grid could easily support a very large number of EVs at present generating

levels. In fact, charging EVs at night would allow the utilities to operate more *efficiently, since they would not have to spool down and spool up as much for fluctuations in demand. EVs would serve as a load leveler.*

I fully agree with the statements about hydrogen, conservation, and developing clean energy.

Shari Prange • Electro Automotive

RE to the Rescue

On April 2, 2006, a severe storm passed through the area. Within a mile of my home, one person died and many were injured when a clothing store collapsed. Roads had to be closed due to debris and downed utility lines. The smell of natural gas was in the air. My entire town of Fairview Heights, Illinois, was without electricity.

The storm rumbled through at 5:20 p.m. My wife Julie was in the bathroom getting ready for work. I quickly ran an extension cord from the solar-electric system control center to the bathroom. I draped a light socket and cord over the existing light fixture, and installed a compact fluorescent bulb for her. Julie was able to complete her morning ritual.

Expecting the electricity to be out for a long time, I ran an extension cord to the kitchen and another one to an upstairs bedroom. I also connected a radio and a TV. Due to the outage, our telephones didn't work. We quickly drained the battery of our cell phone, and used electricity from the solar-electric system to recharge it.

Because it was the first emergency situation since the solar-electric system was installed, I monitored the battery voltage until we went to bed. I also noted how the energy was used. Not knowing how long the utility would be out, we conserved our stored solar energy. As it turned out, we had plenty of electricity for lights, TV, radio, and cell-phone charging.

As a result of this real-emergency use of the system, I've decided to make a few improvements:

- Make sure that all of the emergency light fixtures have on/off switches
- Keep adaptors with each extension cord, so that multiple devices can be attached to the end of each cord
- Keep all emergency items handy, so I don't have to search for them at the time of the emergency
- Make sure that the batteries are maintained at a high level of charge, especially when bad weather is expected
- Modify the system to make it easier to switch in the backup set of batteries

The system performed well in this emergency situation. However, it would be better to have a system large enough to power our refrigerator. Had the outage lasted

longer, food would have spoiled. If an emergency were to occur on a cold night, it would be necessary to use the system to provide electricity to either the furnace or to our corn-burning stove. Currently, the system is not big enough to do that.

Friends and relatives often question the usefulness of my small-scale solar-electric system. I certainly can't claim to be saving money on my electric bill. With only one solar-electric module and four batteries, it doesn't seem to have enough capacity to be of much use. But as I walked through my dark neighborhood last night, I noticed that most houses only had light from candles. One had a noisy, smelly, gas-guzzling generator. On the other hand, I had an abundance of light and a good supply of electricity for other appliances. I'd say that the system was worth the effort.

John Dalhaus • Fairview Heights, Illinois

Solar-Powered Mower

I read your article in *HP113* about battery-powered lawn mowers and it brought to mind how I handle charging mine. Two years ago I decided to move the mower out of the garage to a shed away from the house. To charge it, I had to move it back to the garage to get the electricity. What a pain. I decided to add a solar-electric system to the shed, and bought a pair of small, 12-volt, 5-watt modules.

My mower is a Black & Decker. The wall wart is merely a 120 VAC to 24 VDC transformer, and the charge control is built into the mower. I cut the wires from the wall wart and spliced the panels in series to the mower input connector. This should work for almost any device using a transformer on the wall, if the solar-electric module and transformer output voltage are approximately the same.

Greg Sykora • Livermore, California

Hi Greg, That should work fine as long as the module is small, and the mower does in fact have internal charge regulation. The mower has a sealed battery, and overcharging could damage the battery. If a cordless mower lacks internal charge regulation, then an external charge controller may be necessary.

Michael Welch • Home Power

Toxic PVs?

Somebody on a Web site I frequent claims solar-electric (photovoltaic; PV) modules are "horribly toxic" to manufacture. Can you address whether or not that is true? Thank you,

Carl Chetlan • via e-mail

Hello Carl. Horribly toxic? That is a pretty subjective statement, and it is mostly touted by those with a vested interest in the "conventional" competition (like coal, oil, nuclear, natural gas), or by those who have made the mistake of listening to people with a vested interest in the competition.

First, most new PV manufacturing plants comply with international manufacturing standards, which set environmental standards, among others. Keep in mind that there is no such thing as completely benign electricity generation. All forms of energy have their problems, and every power plant has used toxics in the manufacturing of its equipment.

So what we really want to do is compare PV with the other technologies out there. If you add up the amount of energy that a PV module will produce over its lifetime and also add up the toxics and energy required to make it, and then compare that to other energy sources, you end up with the PV module producing less pollution per KWH than any conventional power plant.

PV's toxics are only produced in their manufacture, and almost all of that is because the energy for manufacturing mostly comes from conventional sources. A conventional power plant continues to produce toxic waste and greenhouse gases over its operational lifetime.

According to a report by the National Renewable Energy Laboratory, "With assumed life expectancies of 30 years, and taking into account the fossil-fuel-based energy used in manufacture, 87 to 97 percent of the energy that PV systems generate won't be plagued by pollution, greenhouse gases, and depletion of resources."

The same report goes on to say, "An average U.S. household uses 830 KWH of electricity per month. On average, producing 1,000 KWH of electricity with solar power reduces emissions by nearly 8 pounds of sulfur dioxide, 5 pounds of nitrogen oxides, and more than 1,400 pounds of carbon dioxide. During its projected 28 years of clean energy production, a rooftop system with a 2-year energy payback and meeting half of a household's electricity use would avoid conventional electrical-plant emissions of more than half a ton of sulfur dioxide, one-third of a ton of nitrogen oxides, and 100 tons of carbon dioxide."

PV manufacturing uses solvents, which is part of what the naysayers' claims are based on. Solvents can be nasty, but they are also filtered and reused, and disposed of properly when no longer usable. The same or similar toxic solvents are used in manufacturing other electrical-generation equipment.

So, what is the bottom line? If you want to be toxic- and pollution-free, don't use any energy, do not drive a car, and do not fly or even take a bus. Heck, even manufacturing a bicycle produces some pollution. But if you want minimal environmental impact while still living a modern lifestyle, you can feel safe switching to PV instead of using nonrenewable electricity.

Michael Welch • Home Power

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Info on state & federal RE incentives. NC Solar Center • www.dsireusa.org

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Sandia National Laboratories PV systems Web site. Design practices, PV safety, technical briefs, battery & inverter testing • www.sandia.gov/pv

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Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Aug. 7–14, '06. Paonia, CO. Camp-Us, RE camp for teens. Discover relationships between energy, nature, spirit, technology & social diversity. Hands-on activities, lectures & recreation. Info: 970-921-5529 • hareef99@yahoo.com • www.youthcamp-us.org

Sept. 16–17, '06. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative vehicles & more. Info: Rocky Mt. Sustainable Living Assoc. • 970-224-FAIR • kellie@poudre.com • www.sustainablelivingfair.org

Carbondale, Paonia & Denver, CO. Workshops & online courses on PV, solar pumping, wind power, RE businesses, microhydro, solar hot water, radiant heating, alternative fuels, green building & women's courses. Solar Energy Intl. (SEI) • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly at Florida Tech to discuss sustainable living, recycling & RE. Info & meeting times: hrobinson@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

IOWA

Iowa City, IA. Iowa RE Assoc. meetings. Call for times. I-Renew • 319-341-4372 • irenew@irenew.org • www.irenew.org

MICHIGAN

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW MEXICO

Oct.–Nov. & Feb.–Mar. each year. Deming, NM. Intro to Homemade Electricity course. Mimbres Valley Learning Center • 505-546-6556 ext. 103 • www.mvlc.us/MVLC-DABCC.htm

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Aug. 7–11, '06. Olivebridge, NY. Workshop: Designing & Building Natural Homes. Info: See SEI in Colorado listings.

NORTH CAROLINA

Beech Mt. & Fletcher, NC. '06 Wind workshops: Aug. 27 & Sept. 9, Intro to Small Scale Wind Energy; Sept. 22–23, Wind Resource Assessment; Oct. 21–22, Small Scale Wind Energy. Info: NC Small Wind Initiative, Appalachian State Univ. • 828-262-7333 • wind@appstate.edu • www.wind.appstate.edu

Saxapahaw, NC. Get Your Solar- Powered Home. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OHIO

Sept. 30–Oct. 1, '06. Athens, OH. Athens Area Sustainability Festival. Workshops on alternative building, RE & sustainable living. Arts & crafts, music & kids' program • 740-674-4300 • fun@susfest.org • www.susfest.org

OREGON

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Sept. 22–23, '06. Kempton, PA. RE & Sustainable Living Festival. RE, natural building, etc. Speakers, exhibits, workshops, music, kids' activities, food & more. Info: Midatlantic RE Assoc. • www.paenergyfest.com

Philadelphia, PA. Philadephia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.com

TENNESSEE

Oct. 19–22, '06. Summertown, TN. Personal oil independence course. Grow your own fuels; put PV on your roof. Info: The Farm • ecovillage@thefarm.org • www.thefarm.org

TEXAS

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

WASHINGTON

Oct. 7, '06. Guemes Island, WA. Intro to RE workshop. Solar-, wind- & hydroelectricity, solar cooking & hot water. Classroom & tours. Info: see SEI in Colorado listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Oct. 9–14, '06. Guemes Island, WA. Solar-Electric Design & Installation workshop. Comprehensive classroom and hands-on training on photovoltaics. Info: See above listing.

Oct. 16–21, ’06. Guemes Island, WA. Solar Home Design & Natural Home Building workshop. Learn to design healthy, energy-smart homes. Classroom, labs, tours. Info: See above listing.

WISCONSIN

Custer, WI. MREA ’06 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

INTERNATIONAL

Internet courses: PV, green building & intl. development. Solar On-Line (SóL) • 720-489-3798 • info@solenergy.org • www.solenergy.org

Internet courses: PV Design & Solar Home Design. Solar Energy International online. Info: See SEI in Colorado listings.

CANADA

Sept. 24–Oct. 1, ’06. Peterborough, Ontario. Intl. Straw Bale Building Conf. Info: ON Straw Bale Bldg. Coalition • www.strawbalebuilding.ca

British Columbia. BC Sustainable Energy Assoc. meetings at chapters throughout province • www.bcsea.org/chapters

Calgary, AB. Alberta Sustainable Home/Office. Open last Sat. of every month, 1–4 PM, private tours available. Cold climate, conservation, RE, efficiency, etc. • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net

CHINA

Oct. 24–27, ’06. Beijing. Great Wall World RE Exhibition. Bringing together power executives, regulators, RE experts, suppliers & investors. Info: Skizttly Zhu • 86-10-62-180-145 • registrar@gwref.org • www.gwref.org

Oct. 31–Nov. 2, ’06. Beijing. China Intl. RE Equipment & Technology Exhibition & Conf. Promotes RE & technology in China. Info: Goodwill Intl. Conference & Exhibition Co. • 86-10-84-518-321 • bjgoodwill@263.net

GERMANY

Sept. 4–8, ’06. Dresden. European PV Conf. & Exhibition. Info: WIP-Munich • 49-89-720-12-735 • pv.conference@wip-munich.de • www.photovoltaic-conference.com

Sept. 28–Oct. 1, ’06. Augsburg. RENEXPO 2006. Exhibits & congress; latest trends & developments in the RE industry. Info: Erneuerbare Energien GmbH • 49-7121-3016-0 • www.holz-energie.de

INDIA

Nov. 6–8, ’06. New Delhi. World Wind Energy Conf. Info: World Wind Energy Assoc. • 49-228-369-40-80 • secretariat@wwindea.org • www.wwindea.org

ITALY

Nov. 16–18, ’06. Milan. PV Tech Expo. Conf. & exhibit for the PV manufacturing industry. Info: ArtEnergy Publishing • 39-02-66-306-866 • info@pvtech.it • www.pvtech.it

NEPAL

Kathmandu. School of RE Ltd. • 97-701-424-4003 • sre@nepalmail.com • www.sre.org.np

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Jan. 8–19, ’07. Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

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Home Power **does not guarantee the quality provided by the businesses listed below—please shop carefully, request references and certifications, and compare.**

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ABS Alaskan, Inc. Anchorage – Fairbanks – Renton, WA Battery systems, Remote power systems, RE systems. OEM design and fabrication. Consultation & design, sales, installation, & service for solar, wind, hydro, and hybrid components and systems since 1989. Web – www.absAK.com. Toll free (800) 235-0689 or (800) 478-7145, email jim@absAK.com.

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Good Power Company, Residential & commercial utility interface or stand alone. Solar, wind & motor generator hybrid systems. Solar water pumping & lighting. Licensed contractor for ALL of Arizona. Free estimates. Call for prompt courteous design, sales, installation, service or repair. Toll free (866) 800-6161, (520) 560-3856 info@goodpowercompany.com. References. ROC195768 ROC200845

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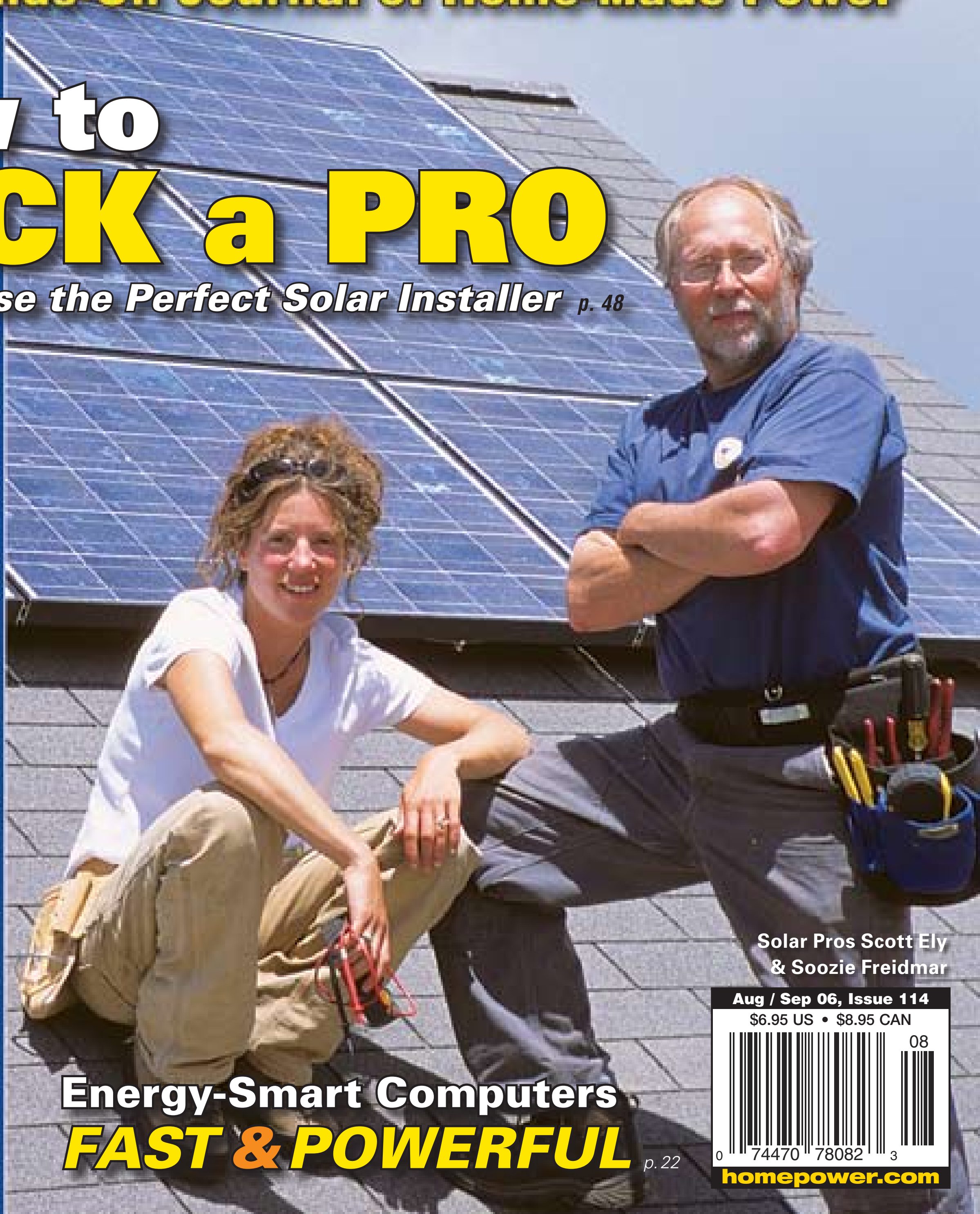

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